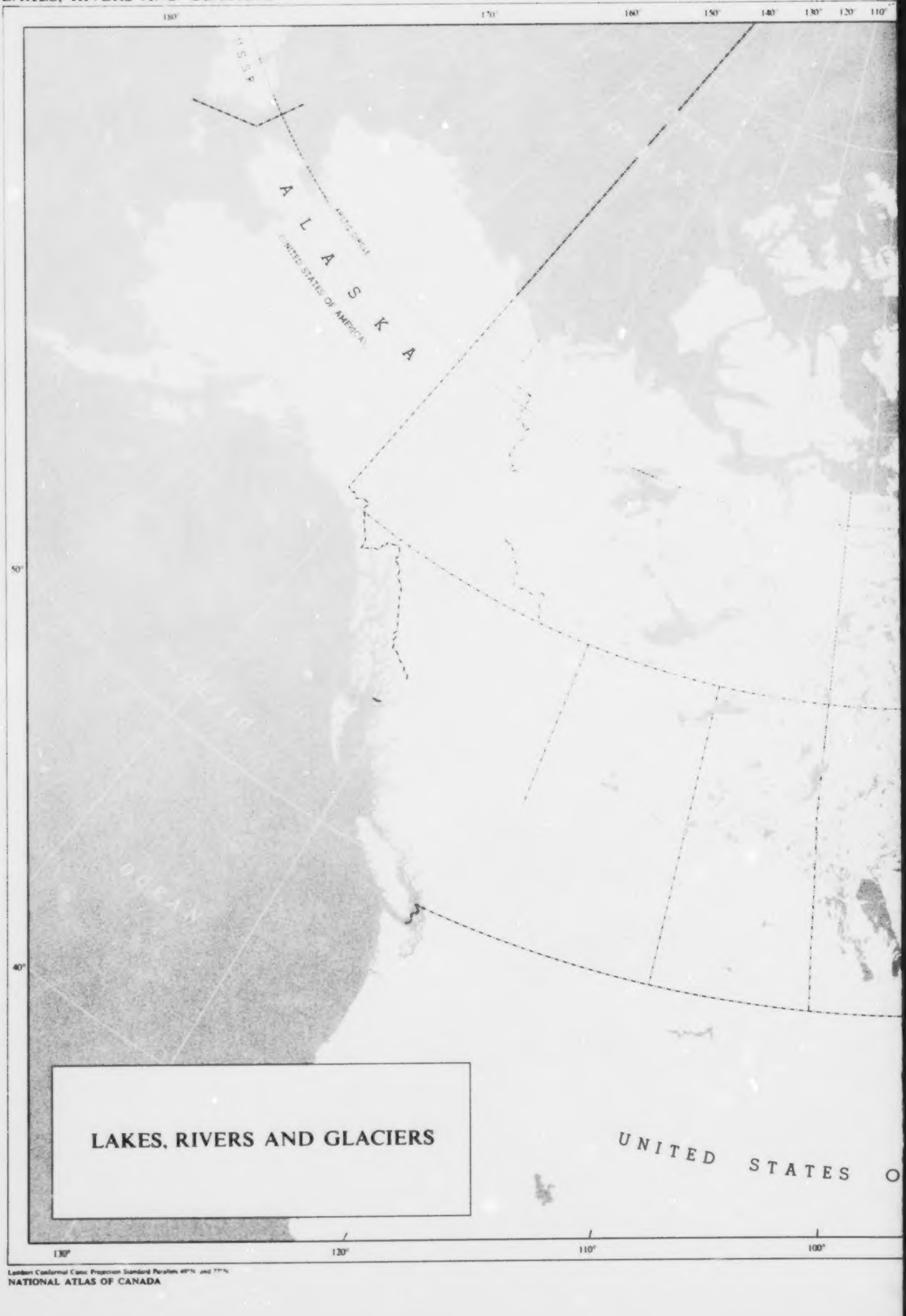
W. B. Scott * E. J. Crossman

FRESHWATER FISHES OF CANADA

Bulletin 184

Fisheries Research Board of Canada, Ottawa 1973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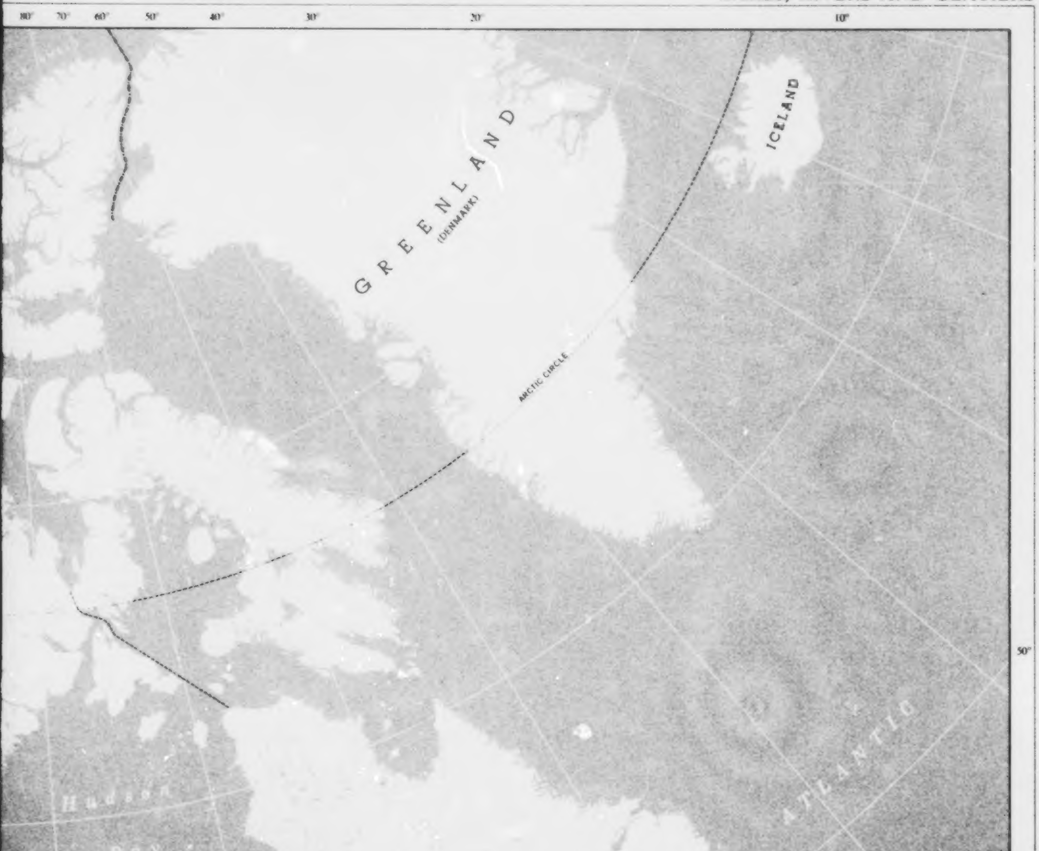
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FRESHWATER
FISHES OF
CANADA

ABOUT THE BOOK . . .

For many years there has been an acute need for a publication on the identification, distribution, biology, and economic importance of the freshwater fishes of Canada. This book provides facts and figures on all species occurring in Canadian fresh waters. The descriptions are based on examinations of specimens carried out expressly for the preparation of this book. For many species the maps will be the first graphic presentation of their Canadian range, and the world distribution is given if the natural range extends beyond Canadian boundaries. Most of the drawings were prepared especially for this book, using typical examples of each species for reference. The artists have been unusually successful in achieving a high degree of accuracy and realism. The keys to the identity of the various fishes were prepared specifically for Canadian fishes and have been tested for more than three years. They include more than one character in each choice in an attempt to separate all of the fishes occurring over the whole of such a large country. Over 1400 references and special Suggested Reading sections cover most of the literature on Canadian freshwater fishes.

The authors, Dr W. B. Scott (left) and Dr E. J. Crossman, with a copy of ***Freshwater Fishes of Canada*** that won the 1974 Fisheries Publication Award of the Wildlife Society, Washington, D.C. (Photo by Bill Robertson)

THE AUTHORS . . .

W. B. Scott was born in Toronto, Ontario, and received his Doctor of Philosophy degree from the University of Toronto in 1950 for his studies on Lake Erie fishes. He has conducted research on freshwater fishes in many parts of Canada from the Great Lakes to Hudson Bay and from Newfoundland to the Barren Grounds of the Northwest Territories. His studies on marine fishes have been carried out in many parts of the Atlantic Ocean from the Grand Banks to the Caribbean. He has written numerous scientific papers and books including *Freshwater Fishes of Eastern Canada*, now in its third edition. He is a member of the Canadian Society of Zoologists, the American Society of Ichthyologists and Herpetologists and the American Fisheries Society. He is also a Fellow of the American Institute of Fishery Research Biologists. He joined the permanent staff of the Royal Ontario Museum in 1947 where he was until 1976 Curator, Department of Ichthyology and Herpetology. In that year he left the ROM to become Executive Director of the Huntsman Marine Laboratory. He is Research Associate, Department of Ichthyology and Herpetology, Royal Ontario Museum and also Professor, Department of Zoology, University of Toronto. Dr. Scott's present address is Huntsman Marine Laboratory, St. Andrews, N.B. E0G 2X0.

E. J. Crossman was born in Niagara Falls, Ontario, and received his Doctor of Philosophy from the University of British Columbia in 1957. Work on Canadian freshwater fishes has carried him throughout Canada, the United States, and Europe. Dr. Crossman's research at this time largely concerns the systematics, biology, and distribution of freshwater fishes, in particular the northern pike, muskellunge and related species. The results of his various studies have appeared in scientific journals and books. He is a member of several international and national professional organizations including the American Society of Ichthyologists and Herpetologists and the Canadian Society of Environmental Biologists. He is Curator in charge of the Department of Ichthyology and Herpetology, Royal Ontario Museum, and Professor in the Department of Zoology, University of Toronto.

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FRESHWATER FISHES OF CANADA

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Department of Ichthyology and Herpetology

Royal Ontario Museum, Toronto

BULLETIN 184

Fisheries Research Board of Canada, Ottawa 1973

Frontispiece: Lake Whitefishes

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Contents

xi EDITOR'S FOREWORD

xiii AUTHORS' COMMENTS — 1979

BACKGROUND INFORMATION

1 Introduction

2 Acknowledgments

4 Canada and Its Fish Fauna

11 Some Important Publications on the Canadian Fish Fauna

15 Instructions on Preparing and Forwarding Specimens for Identification

16 Outline of a Species Account

20 SKETCHES OF ANATOMICAL FEATURES

29 KEY TO THE FAMILIES OF FISHES OCCURRING IN THE FRESH WATERS OF CANADA

SPECIES ACCOUNTS

36 Lampreys — Petromyzontidae
78 Sturgeons — Acipenseridae
101 Gars — Lepisosteidae
111 Bowfin — Amiidae
117 Herrings — Clupeidae
138 Salmons, trouts, whitefishes, graylings — Salmonidae
306 Smelts — Osmeridae
326 Mooneyes — Hiodontidae
337 Mudminnows — Umbridae
346 Pikes — Esocidae
376 Minnows — Cyprinidae
523 Suckers — Catostomidae
588 Catfishes — Ictaluridae
623 Eels — Anguillidae

Contents *(concluded)*

630 Killifishes — Cyprinodontidae
640 Cods — Gadidae
651 Silversides — Atherinidae
656 Sticklebacks — Gasterosteidae
677 Trout-perches — Percopsidae
683 Temperate basses — Percichthyidae
699 Sunfishes — Centrarchidae
751 Perches — Percidae
811 Drums — Sciaenidae
817 Sculpins — Cottidae
850 GLOSSARY
861 INFORMATION ON SPECIMENS USED FOR SPECIES ILLUSTRATIONS
869 REFERENCES
922 INDEX

Colour Plates

Plate I *frontispiece*

facing
90 Plate II Lake sturgeon
Blackfin cisco
Deepwater sculpin

218 Plate III Lake trout
Brook trout
Arctic char

250 Plate IV Northern redbelly dace
Northern redbelly dace
Finescale dace
Finescale dace

442 Plate V Bluegill
Common shiner

730 Plate VI Yellow perch
Rainbow darter
Smallmouth bass
Largemouth bass

EDITOR'S FOREWORD

For some considerable time the Fisheries Research Board has been aware of the need for a thorough study of the freshwater fishes of Canada. The main difficulty was to find qualified scientists who had at their disposal both the necessary resources and the required time. It was not until 1966 that the fortunate arrangement, of which this monograph is the result, was worked out between the Fisheries Research Board and Dr W. B. Scott, Dr E. J. Crossman, and the Royal Ontario Museum (then a part of the University of Toronto).

The Fisheries Research Board, initiator of the project, contributed a large measure of financial support as well as the services of its publications and editorial sections. The Royal Ontario Museum made available the services and facilities, not only of the entire Department of Ichthyology and Herpetology, but also of the highly qualified staff and resources of its library and photography department. It also permitted the Department to make this study its major research project over a period of several years and sponsored the library, laboratory, and field research necessary. Drs Scott and Crossman directed the research, evaluated the results, and wrote the report.

The Fisheries Research Board is proud to present this volume, a tribute to the cooperation between the government agency that initiated and supported the work and the research organization that carried it out. It also expresses its appreciation of the generous outlook of the Director and Board of Trustees of the Royal Ontario Museum that made such cooperation possible.

J. C. Stevenson, Editor and
Director of Scientific Information

Ottawa 1973

AUTHORS' COMMENTS — 1979

This is the second reprinting of Bulletin 184. In preparation, the authors were given the opportunity to make a limited number of improvements to a manuscript prepared prior to 1973. A total revision that would utilize the considerable amount of new information accumulated was not possible. The request in the original version, for help in making the book as accurate and as useful as possible, has resulted in corrections, suggestions, and many notices of range extensions. Many of these are not included as we were not permitted to make changes that would alter pagination or to add or replace illustrations or maps.

We extend our thanks to all who provided such help and remind them that their suggestions have been deferred, not ignored. In fact we repeat our request for new or better information.

The changes in this printing involve (1) the correction of errors throughout the text wherever possible within the limits imposed, (2) a list of species new to the fauna since the original printing, and (3) items that clarify problems discovered in earlier printings, or provide new information available to us in mid-1978. We felt it was imperative to present such information after the passage of 5 years. This information is arranged by species, and for the reader's convenience the number of the first page of the corresponding species account is given.

For entries other than species new to the fauna, space was not adequate to include a citation of the published source of the new information or a specific acknowledgment of a personal communication. That information is available.

Most new entries concern distribution. In general, range extensions were given only when they involved an additional province, an additional watershed, or an obvious empty area on the existing maps.

There is an extensive file of new information and anyone requiring further details should contact the authors. Requests for information specifically on distribution should be directed to the Department of Ichthyology and Herpetology, Royal Ontario Museum, where these records are maintained.

SPECIES NEW TO THE FAUNA

Lethenteron alaskense (the authors, in correspondence, suggest the common name Alaska brook lamprey) was described by Vladykov and Kott using a large series of specimens from Alaska and northwestern Canada.

VLADYKOV, V. D., and E. KOTT. 1978. A new nonparasitic species of the holoarctic lamprey genus *Lethenteron* Creaser and Hubbs, 1922, (Petromyzonidae) from northwestern North America with notes on other species of the same genus. Biol. Pap. Univ. Alaska 19: 74 p.

Salvelinus anaktuvukensis, the angayukaksvrak or old manfish, was described by Morrow (1973), using over 20 specimens, from headwaters in the Brooks Range, Alaska.

Morrow, J. E. 1973. A new species of *Salvelinus* from the Brooks Range, northern Alaska, p. 1–18. *In* Studies on Alaskan fishes. Biol. Pap. Univ. Alaska 13: 41 p.

Salvelinus confluentus (Suckley), bulltrout, has been separated from *S. malma*, Dolly Varden. This newly revived form is known to occur in northwestern North America including Alberta, British Columbia, Yukon Territory, and the Alaska Panhandle but not the upper portion of Alaska.

Cavender, T. M. 1978. Taxonomy and distribution of the bull trout, *Salvelinus confluentus* (Suckley), from the American northwest. Calif. Fish Game 64(3): 139–174.

Campostoma anomalum (Rafinesque), stoneroller — a large number were caught in Nineteen Creek, a tributary of the Thames River, Ontario, in 1972 by Gruchy and associates, and more recently in Niagara and Chatham areas of Ontario.

Gruchy, C. G., R. H. Bowen, and I. M. Gruchy. 1973. First records of the stoneroller (*Campostoma anomalum*) and blackstripe topminnow (*Fundulus notatus*) from Canada. J. Fish. Res. Board Canada 30(5): 683–684.

Notropis photogenis (Cope), silver shiner — 47 specimens, were caught in the Grand River drainage, Ontario, in 1971 by Bowen and others.

Gruchy, C. G., R. H. Bowen, and I. M. Gruchy. 1973. First records of the silver shiner, *Notropis photogenis*, from Canada. J. Fish. Res. Board Canada 30(9): 1379–1382.

Ictiobus niger (Rafinesque), black buffalo — a single specimen was caught in the Canadian waters of western Lake Erie, in 1978 by a commercial fisherman. Specimen deposited in the ROM collection.

Crossman, E. J., and S. J. Nepszy. 1979. First Canadian record of a black buffalo (Osteichthyes: Catostomidae). Can. Field-Natur. 93(3): 304–305.

Pylodictis olivaris (Rafinesque), flathead catfish — a single specimen was caught in the Canadian waters of western Lake Erie, in 1978 by a commercial fisherman. Specimen deposited in ROM collection.

Crossman, E. J., and J. H. Leach. 1979. First Canadian record of a flathead catfish. Can. Field-Natur. 93(2): 179–180.

Noturus insignis (Richardson), margined madtom — four specimens were taken in Quebec in 1971. Subsequent collections have indicated other population and extend the range.

Rubec, P. J., and B. W. Coad. 1974. First record of the margined madtom (*Noturus insignis*) from Canada. J. Fish. Res. Board Canada 31(8): 1430–1431.

Fundulus notatus (Rafinesque), blackstripe topminnow — 48 specimens were caught in the Sydenham River drainage, Lambton County, Ontario, in 1972 by Gruchy and associates.

Gruchy, C. G., R. H. Bowen, and I. M. Gruchy. 1973. First records of the stoneroller (*Campostoma anomalum*) and blackstripe topminnow (*Fundulus notatus*) from Canada. J. Fish. Res. Board Canada 30(5): 683–684.

Lepomis gulosus (Cuvier), warmouth. Between 1966 and 1971 six specimens were collected from Lake Erie, adjacent to Rondeau Provincial Park but went unrecognized. They constitute the first record of this species in Canadian waters.

Platichthys flesus (Linnaeus), the flounder — two specimens were captured in Lake Erie, one in 1974 and one in 1976 by beach seine and otter trawl, respectively, and are in the ROM collection.

EMERY, A. R., and G. TELEKI. 1978. European flounder (*Platichthys flesus*) captured in Lake Erie, Ontario. Can. Field-Natur. 92(1): 89–91.

COMMENTS AND ADDITIONAL INFORMATION

Useful information on distribution in southern Quebec is available in Mongeau, J.-R., A. Courtemanche, G. Masse et B. Vincent. 1974. Cartes de répartition géographique des espèces de poissons au sud du Québec d'après les inventaires ichthyologiques effectués de 1963 à 1972. Faune Que. Rapp. Spec. 4: 92 p. The same sort of treatment for the whole of the province is badly needed.

Drs J. S. Nelson and M. J. Paetz (University of Alberta and Alberta Fish and Wildlife Div., respectively) Edmonton, authors of *Fishes of Alberta*, have prepared a 1976 list entitled *Supplemental Information to the Fishes of Alberta*. That list provides new information on the fishes of that province too extensive to include in this format. Readers interested in fishes occurring in Alberta should contact the above authors.

Petromyzontidae (p. 36). A more accurate map of the distribution of lampreys is available in Hardisty, M. W., and I. C. Potter [ed.] 1971. The biology of lampreys. Vol. 1. Academic Press, Inc., New York, N.Y. 423 p.

Ichthyomyzon fossor (p. 49). Range has now extended much further west to the Hudson Bay watershed in the Birch River of Manitoba.

Acipenser brevirostrum (p. 80). Now known to be much more abundant in the Saint John River, N.B., than previously thought.

Acipenser fulvescens (p. 82). Now known in the Churchill River system of Saskatchewan and north of Edmonton in Alberta.

Salmoninae (p. 144). For Great Lakes *see* Parsons, J. W. 1973. History of the salmon in the Great Lakes, 1850–1970. U.S. Bur. Sport Fish. Wildl., Tech. Pap. 68: 80 p.

Oncorhynchus gorbuscha (p. 148). The Great Lakes population has spread through Lake Superior, south to Lake Huron and is spawning in tributaries of Lake Huron. There is evidence of the development of an even-year spawning run in Lake Superior. A specimen was recently taken in the St. Lawrence near the upstream end of Montreal Island.

Oncorhynchus kisutch (p. 158). Now known to occur near Whitehorse and in the Porcupine River system in Yukon Territory.

Oncorhynchus tshawytscha (p. 172). Arctic coastal distribution apparently continuous eastward to Coppermine, N.W.T.

Salmo clarki (p. 177). Introduced in the Yukon Territory, success presently unknown to us.

Salmo gairdneri (p. 184). Introduced and established in Whitehorse area, Yukon Territory. Area indicated in Alberta was too great, not in North Saskatchewan River below Edmonton, or in the Battle or Red Deer rivers. For Great Lakes *see* MacCrimmon, H. R., and B. L. Gots. 1972. Rainbow trout in the Great Lakes. Ont. Min. Nat. Res. 66 p.

Salvelinus malma (p. 214). *See* comments above regarding separation of *S. confluentus*. Distribution should include portions of the Peace River in Alberta.

Prosopium cylindraceum (p. 286). Distribution in Quebec now known to extend to James Bay coast, and the species occurs farther south in Saskatchewan.

Prosopium williamsoni (p. 291). Distribution now known to include the upper Mackenzie River in Northwest Territories at least to Great Bear Lake, and northeastern Alberta.

Osmerus mordax (p. 310). The illustration indicating a complete lateral line is in error, the description of the lateral line on p. 311 is correct. Apparently two sympatric populations that do not interbreed occur in Heney Lake, Que. Now known to occur in tributaries of Lake Nipigon and headwaters of the Hudson Bay system in Ontario, and the Mackenzie River upstream to Great Slave Lake.

Hiodon alosoides (p. 327). Eastern distribution extends north to the mouth of the Harricanaw River. Distribution extends down Mackenzie River to the level of Fort MacPherson. It does not occur in Lake of the Woods or eastward in the Hudson Bay system. For more recent biological information *see* Donald, D. B., and A. H. Kooyman. 1977. Food, feeding habits, and growth of goldeye, *Hiodon alosoides* (Rafinesque) in waters of the Peace–Athabasca delta. Can. J. Zool. 55(6): 1038–1047.

Hiodon tergisus (p. 333). Now known east to the headwaters of the Hudson Bay system in western Ontario, and from south central Alberta.

Umbra limi (p. 341). Now known to be present in at least two localities on the north shore of Lake Superior, in the headwaters of the Hudson Bay system in western Ontario, in the Assiniboine River in western Manitoba, and lakes to the northeast of Lake Winnipegosis in central Manitoba.

Esox lucius (p. 356). Now known to be absent from the Leaf River north in Ungava, Que.

Carassius auratus (p. 389). Now known to occur in Quebec and Manitoba.

Chrosomus eos (p. 392). Now reported to occur also in the lower Mackenzie River, and in the northeastern corner of Alberta.

Chrosomus neogaeus (p. 396). Reported to occur in western Manitoba and central Saskatchewan.

Couesius plumbeus (p. 401). New records now extend the distribution in Quebec to the coastline of James and Hudson bays north to the Leaf River.

Cyprinus carpio (p. 407). Now known to occur as far north in Manitoba as the York Factory area.

Hybognathus hankinsoni (p. 414). Now reported to occur in northeastern British Columbia and in two drainages in northern Alberta.

Nocomis biguttatus (p. 427), and *Nocomis micropogon* (p. 431). Some discrepancies exist between the descriptions and the illustrations in such features as numbers of scales and fin ray counts. In all such cases, reliance should be placed on the Descriptions that are based on examination of specimens. Large adult specimens are sorely needed and these can best be captured by hook and line. *N. biguttatus* is now known from several tributaries of Lake Ontario.

Nocomis micropogon (p. 431). Reported from the Ottawa River system in eastern Ontario.

Notropis atherinoides (p. 440). We have been informed that specimens have been collected in five localities on the Hayes River, Man., extending the known range to within 8.5 miles (13.7 km) of Hudson Bay.

Notropis heterodon (p. 454). Now known to extend northward in northwestern Ontario to Sioux Lookout district.

Notropis heterolepis (p. 456). Now known to occur in Wollaston Lake in northeastern Saskatchewan and possibly between this area and where indicated on the map. The inset map should indicate its presence in the U.S. westward to a line through Kansas.

Notropis hudsonius (p. 459). A very useful bibliography is available: Shapiro, S. M. 1975. A bibliography of the spottail shiner, *Notropis hudsonius* (Clinton) (Pisces: Cyprinidae). Mass. Coop. Fish. Res. Unit, Univ. Mass. Publ. 43: 48 p.

Notropis rubellus (p. 463). Now known to occur as far north in Ontario as the Cochrane district. Discrepancy in text and illustration concerning position of pelvic fins. Text is correct.

Pimephales promelas (p. 480). Now reported from the Peace River in British Columbia.

Semotilus corporalis (p. 511). Now known north to the mouth of La Grande Rivière (=Ft. George R.) at James Bay, Que.

Semotilus margarita (p. 515). Now known from the Kazan River system (Northwest Territories) in extreme northeastern Saskatchewan.

Carpiodes cyprinus (p. 528). Does occur in Lake Ontario, and occurs northward in Alberta at least to the Edmonton area.

Catostomus commersoni (p. 538). The record in southeastern Yukon Territories is an error (=*C. catostomus*) and that bulge in the range should be deleted.

Moxostoma anisurum (p. 564). Occurs also in the North Saskatchewan River in Alberta and probably in Saskatchewan.

Ictalurus melas (p. 591). Recent work indicates that this species has probably always been present and widespread in Ontario but has not been separated from specimens of *I. nebulosus*. The two species can be readily separated on the basis of the shape of the supraethmoid depression, that in *I. melas* is broader and lacks mesial processes.

Ictalurus nebulosus (p. 598). Now known to occur on the north shore of Lake Superior at least in tributaries of Lake Nipigon.

Ictalurus punctatus (p. 604). Occurs more widely in Manitoba. It has been reported from northern Lake Winnipegosis and the Little Waterhen River.

Noturus gyrinus (p. 615). For biological information *see* Case, B. 1970. An ecological study of the tadpole madtom, *Noturus gyrinus*, with special reference to movements and population fluctuations. M.Sc. diss. Univ. Man.

Anguilla rostrata (p. 624). Apparently introduced in Saskatchewan in 1953 and now reported from the South Saskatchewan River in Alberta.

Labidesthes sicculus (p. 652). Now known to occur at least on the south shore of Lake Superior, and farther downstream in the St. Lawrence River system.

Percopsis omiscomaycus (p. 678). Now known as far north as La Grande Rivière (=Ft. George R.) near the coast of James Bay in Quebec.

Morone americana (p. 684). Now known from the Great Lakes as far up as Lake St. Clair.

Morone chrysops (p. 689). A single specimen was collected on Aug. 18, 1975, in Lake Superior at Presque Isle Harbour, Marquette, Mich. This represents the first valid record for Lake Superior.

Lepomis cyanellus (p. 710). Several specimens have been collected by ROM staff in Lincoln and Wentworth counties, Ontario, thus extending the range into the Niagara district. In 1976, several specimens were also captured in two localities in the Nith River, Grand River drainage.

Micropterus dolomieui (p. 728). The mathematical expression of the length–weight relationship of Rowan (1962) is now known to be an error in Rowan 1962 and should not be used.

Pomoxis nigromaculatus (p. 745). Reported in northern Manitoba from the Nelson River, 150 miles downstream from Lake Winnipeg.

Percidae (p. 751). For extensive information on members of the family *see* Proc. 1976 Percid Int. Symp., J. Fish. Res. Board Canada 34(10), and Proc. 1978 Symp. on Selected Coolwater Species. Spec. Publ. Amer. Fish. Soc.

Perca flavescens (p. 755). For the latest in the discussion of the separate status of the perches of North America and Europe *see* Collette, B. B., and P. Banarescu. 1977. Systematics and zoogeography of the fishes of the family Percidae, J. Fish. Res. Board Canada 34(10): 1450–1463. This species is now known to occur in Manitoba downstream to Hudson Bay in the Hayes River.

Stizostedion canadense (p. 762). Distribution now known to include the Churchill River system in Manitoba and Saskatchewan.

Etheostoma exile (p. 783). Reported in the Churchill River system both in eastern Saskatchewan and in Southern Indian Lake, Man.

Etheostoma nigrum (p. 793). Reported from the Harricanaw and Moose rivers at Moosonee, Ont.

Percina caprodes (p. 797). Now recorded from the Medley River, a tributary to Cold Lake on the Alberta side. This is the first record for the province.

Cottus bairdi (p. 826). Now known to occur in central Quebec, at least in Lac du Lagopede (James Bay drainage).

Cottus cognatus (p. 830). Reported from the Milk River in Alberta (Missouri system). Valid records east of the Saguenay River, Que., are lacking. The species is absent in the Matamek River and probably absent in the Pigou and Beauleau rivers to the east.

Cottus ricei (p. 839). Now recorded in Southern Indian Lake of the Churchill River system in Manitoba.

Myoxocephalus quadricornis (p. 842). Now reported to occur in the Beaufort Sea drainage of northern Yukon Territory, Lake Athabasca and Black Lake in Saskatchewan, Upper Waterton Lake in Alberta (first record for the province), and the Moose and Kisagami rivers (James Bay) in Ontario. Some of these records may be based on the marine form.

BACKGROUND INFORMATION

INTRODUCTION

The preparation of a monograph on the freshwater fishes of Canada was first suggested to Dr Scott in 1956 by Dr J. L. Kask, at that time Chairman of the Fisheries Research Board. It was not possible then to accept Dr Kask's offer although there was considerable interest in the idea. Ten years later the question was raised again, this time by the Editor of the Fisheries Research Board, Dr J. C. Stevenson. After much deliberation and discussion within the Royal Ontario Museum (ROM), at that time a part of the University of Toronto, a contract was drawn up in 1966 between the Fisheries Research Board on the one hand and the authors, the Royal Ontario Museum, and the University of Toronto on the other.

It was logical to select the Royal Ontario Museum as the site for such a project since it houses the largest collection of Canadian freshwater fishes available anywhere. Also available were artists, research assistants, photographic services, trained clerical assistants, and graduate students from the University of Toronto and other universities. The graduate students were especially important for they played a most valuable role in appraising and testing various parts of the project such as keys, distribution maps, and descriptions of fishes, as well as in providing ideas.

It was the authors' decision to work toward a three-year target date for completion of the project, and they specified the completion date as March 31, 1970. They were overly optimistic, perhaps, but were unaware at the time that the Museum was entering upon the most active period in its history, that their involvement in university teaching and graduate programs would treble, and that professional demands upon their time and energy would increase manyfold. It appears to be a common misconception that museum laboratories are quiet, secluded places, where bearded scholars quietly pursue their studies. Such is far from the truth. Museum laboratories are exciting places where specimens, information, and requests for assistance pour in from all parts of the globe from colleagues, teachers, former students, would-be-students, and interested public. Research programs must be planned, replanned, and executed, and routine studies on the collection continued. In such conditions, the authors feel fortunate to have been able to complete the project.

Preparation of much of the material in this book has been a depressing experience. Time after time when gathering the material for the write-up of a particular species, it would be found that the species had either disappeared from much of its former range (as is the case of the striped bass in the St. Lawrence, the whitefish and the lake trout in the Great Lakes, and the arctic char in Frobisher Bay) or that it had been completely extirpated from the North American scene (as in the case of the blue walleye). It also became apparent that many species now rare or absent were once more widely distributed, particularly in the lower Great Lakes region. This is particularly true of many of the minnows that prefer clear water and low turbidity.

Texts of this type become more useful with revisions based on constructive criticisms. The keys used were published separately as a Miscellaneous Publication of the Royal Ontario Museum entitled, *Checklist of Canadian Freshwater Fishes with Keys for Identification*. Many colleagues provided useful criticisms of that work and these have been embodied in this text.

It is the hope of the authors that this text will perform a useful service by highlighting the lack of information on many aspects of the biology of many Canadian fish species. Particularly glaring is our ignorance of the basic life history of many common species. Some of these would make useful subjects for university studies rather than the exotic species now used so frequently by behaviourists. The darters would seem to be most promising candidates for behavioural studies but cottids, minnows, and centrarchids also have much to offer in this field.

While materials for this Bulletin were being prepared and written, four prominent ichthyologists, P. H. Greenwood, D. E. Rosen, S. H. Weitzman, and G. S. Myers, prepared a radically new classification of fishes entitled, *Phyletic Studies of Teleostean Fishes, with a provisional classification of living forms.* Although preferring to follow, with modifications, the more traditional classifications of Regan, Norman, and Berg, the authors are cognizant of the pertinence of the new approach. They have not adopted it in the present text largely because they believe a number of modifications will be made to it in its early years, indeed, some of these have already appeared, *see* Weitzman, Copeia 1967(3), and also since it was thought that the present text would be more useful to Canadians if presented in a more or less familiar form. Subsequent editions of *Freshwater Fishes of Canada* will undoubtedly be more in line with the new classification.

It is anticipated that this work will be revised so that new knowledge, which accumulates so rapidly, can be added. Readers are, therefore, urged to bring to the attention of the writers errors or omissions found in the following pages. Simply write to either author at the Department of Ichthyology and Herpetology, Royal Ontario Museum, Toronto, Canada M5S 2C6.

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W B Scott.

E J Crossman

CANADA AND ITS FISH FAUNA

Canada, the largest country in the western hemisphere and the second largest country in the world, has an area of more than 3,850,000 square miles, compared with over 8,600,000 square miles of the Union of Soviet Socialist Republics. It occupies the northern half of the North American continent, exclusive of Alaska and Greenland. In latitude, it extends from Middle Island, Lake Erie, at 41°41'N, to the North Pole, but the northernmost point of land is Cape Columbia, on Ellesmere Island, a straight-line distance of 2875 miles from Middle Island. Longitudinally it extends from Cape Spear, Newfoundland, at 52°37'W, to Mount St. Elias, Yukon Territory at 141°W, a distance of 3233 miles.

Of Canada's total area, 291,571 square miles, or 7.6% are exceedingly important fresh waters, which rank among the most valuable freshwater reserves in the world. They include not only the extensive Great Lakes, which, with the exception of Lake Michigan, are shared with the United States, but also such huge northern lakes as Great Slave and Great Bear that have areas of approximately 11,000 and 12,000 square miles, respectively, compared to Lake Erie's 10,000 square miles, and mighty rivers such as the St. Lawrence, the Nelson, and the Mackenzie with lengths of 1900, 1600, and 2635 miles, respectively.

Although relatively rich in supplies of fresh water, Canada is not rich in species of fishes, but rather, is depauperate, largely as a result of the relatively recent retreat of the Pleistocene ice. The total freshwater fish fauna consists of 24 families and 177 species, 181 if we include the introduced and established brown trout, carp, goldfish, and tench. Some appreciation of Canada's lack of richness of species can be gained by comparing it with the Great Lakes state of Ohio which has approximately 170 species. Actually, 5 families, the Salmonidae, Cyprinidae, Catostomidae, Percidae, and Cottidae contribute 70% of the fauna.

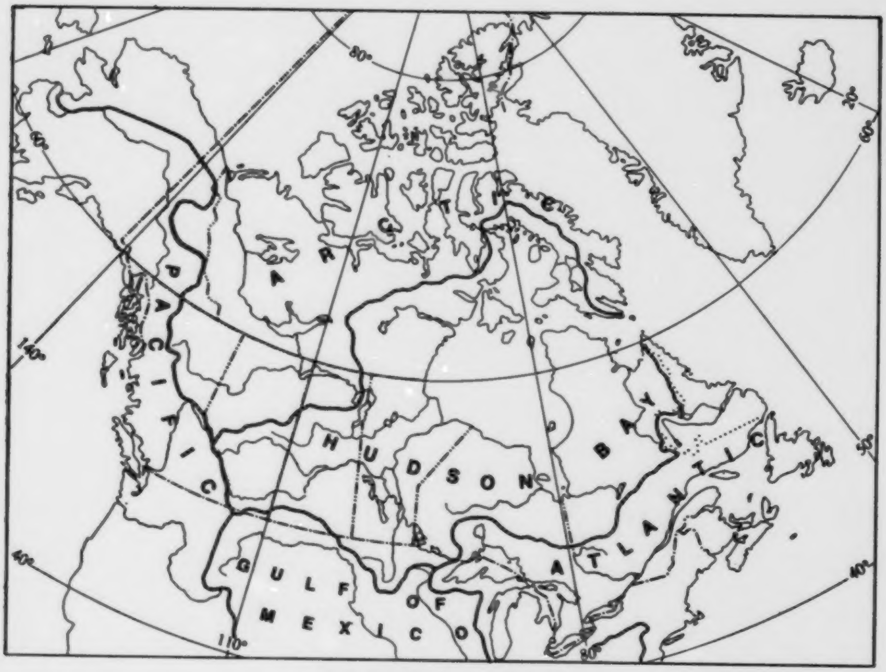
However, from a fisherman's viewpoint, what Canada lacks in quantity is compensated for in quality. The country has some of the finest salmon, trout, and char populations available anywhere, although the inroads of resource development and so-called technological advance threaten the continued existence of even the most remote.

The following summary shows the distributions of 181 species by province and by major watershed.

NUMBER OF SPECIES BY GEOGRAPHIC AREA AND DRAINAGE BASIN IN A FAUNA OF 181 SPECIES, 1971

By Geographic Area

Insular Newfoundland	20	**Manitoba**	79
Labrador (Nfld.)	21	**Saskatchewan**	60
Nova Scotia	34	**Alberta**	51
Prince Edward Island	19	**British Columbia**	71
New Brunswick	48	**Northwest Territories**	41
Quebec	105	**Yukon Territory**	31
Ontario	132	**Alaska**	40


ARCTIC
PACIFIC
HUDSON BAY
ATLANTIC
GULF OF MEXICO
80°
60°
140°
40°
110°
80°
40°
55°
60°
20°

Drainage Basins of Canada

By Drainage Basin

Atlantic	142
Hudson Bay	94
Arctic	56
Pacific	67
Gulf of Mexico	27

Atlantic Drainage Basin — 142 Species

(*indicates an introduced species)

Lampetra lamottei
Ichthyomyzon fossor
I. unicuspis
Petromyzon marinus
Acipenser brevirostrum
A. fulvescens
A. oxyrhynchus
Lepisosteus oculatus
L. osseus
Amia calva
Alosa aestivalis
A. pseudoharengus
A. sapidissima
Dorosoma cepedianum
Coregonus alpenae
C. artedii
C. canadensis
C. clupeaformis
C. hoyi
C. johannae

Atlantic Drainage Basin (cont.)

C. kiyi
C. nigripinnis
C. reighardi
C. zenithicus
*Oncorhynchus gorbuscha**
*O. kisutch**
*O. nerka**
*O. tshawytscha**
Prosopium coulteri
P. cylindraceum
*Salmo clarki**
*S. gairdneri**
S. salar
*S. trutta**
Salvelinus alpinus
S. fontinalis
S. namaycush
Osmerus mordax
Hiodon alosoides
H. tergisus
Umbra limi
Esox americanus
E. lucius
E. masquinongy
E. niger
*Carassius auratus**
Chrosomus eos
C. neogaeus
Clinostomus elongatus
Couesius plumbeus
*Cyprinus carpio**
Exoglossum maxillingua
Hybognathus hankinsoni
H. nuchalis
Hybopsis storeriana
H. x-punctata
Nocomis biguttatus
N. micropogon
Notemigonus crysoleucas
Notropis anogenus
N. atherinoides
N. bifrenatus
N. cornutus
N. emiliae
N. heterodon
N. heterolepis
N. hudsonius
N. rubellus
N. spilopterus
N. stramineus
N. umbratilis
N. volucellus
Pimephales notatus
P. promelas
Rhinichthys atratulus
R. cataractae
Semotilus atromaculatus
S. corporalis
S. margarita
Carpiodes cyprinus
Catostomus catostomus
C. commersoni
Erimyzon sucetta
Hypentelium nigricans
Ictiobus cyprinellus
Minytrema melanops
Moxostoma anisurum
M. carinatum
M. erythrurum
M. hubbsi
M. macrolepidotum
M. valenciennesi
Ictalurus melas
I. natalis
I. nebulosus
I. punctatus
Noturus flavus
N. gyrinus
N. miurus
Anguilla rostrata
Fundulus diaphanus
F. heteroclitus
Lota lota
Microgadus tomcod
Labidesthes sicculus
Apeltes quadracus
Culaea inconstans
Gasterosteus aculeatus
G. wheatlandi
Pungitius pungitius

Atlantic Drainage Basin (*cont.*)

Percopsis omiscomaycus
Morone americana
M. chrysops
M. saxatilis
Ambloplites rupestris
Lepomis auritus
L. cyanellus
L. gibbosus
L. macrochirus
L. megalotis
Micropterus dolomieui
M. salmoides
Pomoxis annularis
P. nigromaculatus
Ammocrypta pellucida
Etheostoma blennioides
E. caeruleum
E. exile
E. flabellare
E. microperca
E. nigrum
Perca flavescens
Percina caprodes
P. copelandi
P. maculata
Stizostedion canadense
S. vitreum
Aplodinotus grunniens
Cottus bairdi
C. cognatus
C. ricei
Myoxocephalus quadricornis

Hudson Bay Drainage Basin — 94 Species

Ichthyomyzon castaneus
I. unicuspis
Acipenser fulvescens
Coregonus artedii
C. clupeaformis
C. nigripinnis
C. zenithicus
*Oncorhynchus gorbuscha**
*O. keta**
*O. nerka**
*O. tshawytscha**
Prosopium cylindraceum
P. williamsoni
*Salmo clarki**
*S. gairdneri**
S. salar
*S. trutta**
Salvelinus alpinus
S. fontinalis
S. malma
S. namaycush
Thymallus arcticus
Hiodon alosoides
H. tergisus
Umbra limi
Esox lucius
E. masquinongy
*Carassius auratus**
Chrosomus eos
C. neogaeus
Couesius plumbeus
*Cyprinus carpio**
Hybognathus hankinsoni
H. nuchalis
Hybopsis storeriana
Nocomis biguttatus
Notemigonus crysoleucas
Notropis atherinoides
N. blennius
N. cornutus
N. dorsalis
N. heterolepis
N. hudsonius
N. rubellus
N. stramineus
N. volucellus
Pimephales notatus
P. promelas
Platygobio gracilis
Rhinichthys atratulus

Hudson Bay Drainage Basin (cont.)

R. cataractae
Semotilus atromaculatus
S. corporalis
S. margarita
Carpiodes cyprinus
Catostomus catostomus
C. commersoni
C. platyrhynchus
Ictiobus cyprinellus
Moxostoma anisurum
M. macrolepidotum
Ictalurus melas
I. nebulosus
I. punctatus
Noturus flavus
N. gyrinus
Fundulus diaphanus
Lota lota
Culaea inconstans
Gasterosteus aculeatus
Pungitius pungitius
Percopsis omiscomaycus
Morone chrysops
Ambloplites rupestris
Lepomis cyanellus
L. gibbosus
L. macrochirus
L. megalotis
Micropterus dolomieui
M. salmoides
Pomoxis nigromaculatus
Etheostoma exile
E. nigrum
Perca flavescens
Percina caprodes
P. maculata
P. shumardi
Stizostedion canadense
S. vitreum
Aplodinotus grunniens
Cottus bairdi
C. cognatus
C. ricei
Myoxocephalus quadricornis

Arctic Drainage Basin — 56 Species

Lampetra japonica
Coregonus artedii
C. autumnalis
C. clupeaformis
C. laurettae
C. nasus
C. nigripinnis
C. sardinella
C. zenithicus
Oncorhynchus gorbuscha
O. keta
O. nerka
O. tshawytscha
Prosopium coulteri
P. cylindraceum
P. williamsoni
Salmo gairdneri
*S. trutta**
Salvelinus alpinus
*S. fontinalis**
S. malma
S. namaycush
Stenodus leucichthys
Thymallus arcticus
Hypomesus olidus
Osmerus mordax
Hiodon alosoides
Dallia pectoralis
Esox lucius
Chrosomus eos
C. neogaeus
Couesius plumbeus
Hybognathus hankinsoni
Mylocheilus caurinus
Notropis atherinoides
N. hudsonius
Pimephales promelas
Platygobio gracilis
Ptychocheilus oregonensis
Rhinichthys cataractae

Arctic Drainage Basin (cont.)

Richardsonius balteatus
Semotilus margarita
Lota lota
Culaea inconstans
Pungitius pungitius
Catostomus catostomus
C. commersoni
C. macrocheilus
Percopsis omiscomaycus
Etheostoma exile
Perca flavescens
Stizostedion vitreum
Cottus asper
C. cognatus
C. ricei
Myoxocephalus quadricornis

Pacific Drainage Basin (+ Bering Sea) — 67 Species

Entosphenus tridentatus
Lampetra ayresi
L. japonica
L. richardsoni
Acipenser medirostris
A. transmontanus
*Alosa sapidissima**
Coregonus autumnalis
C. clupeaformis
C. nasus
C. sardinella
Oncorhynchus gorbuscha
O. keta
O. kisutch
O. nerka
O. tshawytscha
Prosopium coulteri
P. cylindraceum
P. williamsoni
Salmo clarki
S. gairdneri
*S. trutta**
*Salvelinus fontinalis**
S. malma
S. namaycush
Stenodus leucichthys
Thymallus arcticus
Hypomesus olidus
Osmerus mordax
Spirinchus thaleichthys
Thaleichthys pacificus
Dallia pectoralis
Esox lucius
Acrocheilus alutaceus
*Carassius auratus**
Couesius plumbeus
*Cyprinus carpio**
Hybognathus hankinsoni
Mylocheilus caurinus
Notropis atherinoides
Ptychocheilus oregonensis
Rhinichthys cataractae
R. falcatus
R. osculus
Richardsonius balteatus
*Tinca tinca**
Catostomus catostomus
C. columbianus
C. commersoni
C. macrocheilus
C. platyrhynchus
*Ictalurus melas**
*I. nebulosus**
Lota lota
Gasterosteus aculeatus
Percopsis omiscomaycus
*Lepomis gibbosus**
*Micropterus dolomieui**
*M. salmoides**
*Pomoxis nigromaculatus**
*Perca flavescens**
Cottus aleuticus
C. asper
C. bairdi
C. cognatus
C. confusus
C. rhotheus

Gulf of Mexico Drainage Basin — 27 Species

Prosopium williamsoni
*Salmo clarki**
*S. gairdneri**
*S. trutta**
Esox lucius
*Carassius auratus**
Chrosomus eos
C. neogaeus
Couesius plumbeus
*Cyprinus carpio**
Hybognathus hankinsoni
H. nuchalis
Pimephales promelas
Platygobio gracilis
Rhinichthys cataractae
Semotilus margarita
Catostomus catostomus
C. commersoni
C. platyrhynchus
Moxostoma macrolepidotum
Noturus flavus
Lota lota
Culaea inconstans
Etheostoma exile
Perca flavescens
Stizostedion canadense
Cottus bairdi

The following fishes have not been included among the "Canadian freshwater fishes," either because the species involved are tropical exotics that have been introduced into an extremely restricted locality in one province, or because the species are essentially marine forms sometimes found in the lower reaches of coastal streams:

— five species of tropical aquarium fishes have become established in Cave and Basin Hotspring, Banff National Park, Alta., apparently since about 1954 (McAllister 1969; Paetz and Nelson 1970). These include five species in two families, as follows:

Poeciliidae — live bearers
  Poecilia latipinna (Lesueur) — sailfin molly
  Poecilia reticulata Peters — guppy
  Xiphophorus helleri Heckel — green swordtail
  Gambusia affinis (Baird and Girard) — mosquitofish
Cichlidae — cichlids
  Cichlasoma nigrofasciatum (Günther) — convict cichlid

— a number of species of marine fishes have been reported by many authors from fresh or brackish waters of Canadian streams or rivers flowing into the Atlantic, Arctic or Pacific basins. The following list does not purport to be complete but does include all species mentioned in the recent literature:

Squalidae — dogfish sharks
  Squalus acanthias Linnaeus — spiny dogfish
Clupeidae — herrings
  Clupea harengus pallasi Valenciennes — Pacific herring
Embiotocidae — surfperches
  Cymatogaster aggregata Gibbons — shiner perch
Cottidae — sculpins
  Clinocottus acuticeps (Gilbert) — sharpnose sculpin
  Leptocottus armatus Girard — Pacific staghorn sculpin
  Myoxocephalus quadricornis (Linnaeus) — fourhorn sculpin

Cyclopteridae — lumpfishes and snailfishes
    Cyclopterus lumpus Linnaeus — lumpfish
Ammodytidae — sand lances
    Ammodytes americanus DeKay — American sand lance
Bothidae — lefteye flounders
    Scophthalmus aquosus (Mitchill) — windowpane
Pleuronectidae — righteye flounders
    Liopsetta putnami (Gill) — smooth flounder
    Platichthys stellatus (Pallas) — starry flounder
    Pseudopleuronectes americanus (Walbaum) — winter flounder

SOME IMPORTANT PUBLICATIONS ON THE CANADIAN FISH FAUNA

The most comprehensive history of ichthyology in Canada was prepared by the late J. R. Dymond for the 50th anniversary of the American Society of Ichthyologists and Herpetologists and was published by that society in 1964. Dymond included a chronological history and a list of the contributions made by federal and provincial governments, universities, and museums. The growth of distributional information was traced to 1961, the locations of major collections of fishes were given, and a chronological list of important fishery publications was presented. This list, modified to emphasize freshwater fishes and updated to 1970, is as follows:

1771	Forster, J. R.	Catalogue of the animals of North America containing an enumeration of the known quadrupeds, birds, reptiles, fish.
1792	Pennant, T.	Arctic zoology. Fishes. 2nd ed.
1836	Richardson, J.	Fauna Boreali-Americana; or the zoology of the northern parts of British America: part third *The fish*.
1850	Agassiz, J. L. R.	Lake Superior. Its physical character, vegetation, and animals, compared with those of other and similar regions.
1852	Perley, M. H.	Reports of the sea and river fisheries of New Brunswick.
1858	Ure, G. P.	Fishes. *In* The handbook of Toronto, by a member of the press.
1862	Gill, T. N.	Catalogue of the fishes of the eastern coast of North America from Greenland to Georgia.

1863	Fortin, Pierre	List of the cetacea, fishes, crustacea and mollusca, which now inhabit and have been inhabiting the Canadian shores of the Gulf of St. Lawrence and are objects of fishing operations, whether on a large or small scale, and which are used as bait, etc.
1864	Fortin, Pierre	Continuation of the list of fish of the Gulf and River St. Lawrence.
1865	Fortin, Pierre	Continuation of the list of fishes found in the Gulf and River St. Lawrence.
1865	Gill, T. N.	Synopsis of the fishes of the Gulf of St. Lawrence and Bay of Fundy.
1865	Small, H. B.	The animals of North America. ser. 2. Fresh-water fish.
1866	Fortin, Pierre	Continuation of the list of fishes taken in the Gulf and River St. Lawrence.
1866a, b	Lord, J. K.	The naturalist in Vancouver Island and British Columbia.
1866	Knight, T. F.	Fishes of Nova Scotia. Descriptive catalogue of fishes of Nova Scotia.
1873	Adams, A. L.	Field and forest rambles, with notes and observations on the natural history of eastern Canada.
1875	Provancher (l'Abbé)	Faune canadienne. Les poissons. vol. 7.
1876	Provancher (l'Abbé)	Faune canadienne. Les poissons. vol. 8.
1882	Jones, J. M.	List of the fishes of Nova Scotia.
1886	Whiteaves, J. F.	Catalogue of Canadian Pinnipedia, Cetacea, fishes and marine Invertebrata.
1892	Wright, R. R.	Preliminary report on the fish and fisheries of Ontario.
1895	Eigenmann, C. H.	Results of explorations in western Canada and the northwestern United States.
1896	Low, A. P.	Report on explorations in the Labrador Peninsula along the East Main, Koksoak, Hamilton, Manicuagan and portions of other rivers in 1892–93–94–95. *In* Ann. Rep. Geol. Surv. Canada, 1895, App. III.
1896b	Cox, Philip	Catalogue of the marine and freshwater fishes of New Brunswick.
1897	Montpetit, A. N.	Les poissons d'eau douce du Canada.
1898	Thompson, E. S.	A list of the fishes known to occur in Manitoba.

1907a	Evermann, B. W., and E. L. Goldsborough	A check list of the freshwater fishes of Canada.
1908	Nash, C. W.	Manual of vertebrates of Ontario.
1909	Kendall, W. C.	The fishes of Labrador.
1910	Evermann, B. W., and H. B. Latimer	The fishes of the Lake of the Woods and connecting waters.
1913	Halkett, A.	Check list of the fishes of the Dominion of Canada and Newfoundland.
1915	Bensley, B. A.	Fishes of Georgian Bay.
1919	Whitehouse, F. C.	Notes on some fishes of Alberta and adjacent waters.
1922	Dymond, J. R.	A provisional list of the fishes of Lake Erie.
1926	Dymond, J. R.	The fishes of Lake Nipigon.
1927	Dymond, J. R., and J. L. Hart	The fishes of Lake Abitibi (Ontario) and adjacent waters.
1929	Dymond, J. R., J. L. Hart, and A. L. Pritchard	The fishes of the Canadian waters of Lake Ontario.
1933	Dymond, J. R.	The coregonine fishes of Hudson and James bays. *In* Biological and oceanographic conditions in Hudson Bay.
1933	Vladykov, V. D.	Biological and oceanographic conditions in Hudson Bay. 9. Fishes from the Hudson Bay region (except the Coregonidae).
1934	Dymond, J. R., and V. D. Vladykov	The distribution and relationship of the salmonoid fishes of North America and North Asia.
1935	Vladykov, V. D., and R. A. McKenzie	The marine fishes of Nova Scotia.
1936	Mélançon, C.	Les poissons de nos eaux.
1939	Dymond, J. R.	The fishes of the Ottawa region.
1943	Hinks, David	The fishes of Manitoba.
1947	Dymond, J. R.	A list of the freshwater fishes of Canada east of the Rocky Mountains, with keys.
1949	Rawson, D. S.	A check list of the fishes of Saskatchewan.
1952	Wynne-Edwards, V. C.	Fishes of the Arctic and subarctic. *In* Freshwater vertebrates of the Arctic and subarctic.
1952	Legendre, V.	Clef des poissons de pêche sportive et commerciale de la Province de Québec.
1953	Livingstone, D. A.	The fresh water fishes of Nova Scotia.

1953	Walters, V.	The fishes collected by the Canadian Arctic Expedition, 1913–1918, with additional notes on the ichthyofauna of western Arctic Canada.
1955	Walters, V.	Fishes of the western Arctic America and eastern Arctic Siberia. Taxonomy and Zoogeography.
1956	Lindsey, C. C.	Distribution and taxonomy of fishes in the Mackenzie drainage of British Columbia.
1957	Backus, R. H.	The fishes of Labrador.
1959	Scott, W. B., and E. J. Crossman	The freshwater fishes of New Brunswick: a checklist with distributional notes.
1963	MacKay, H. H.	Fishes of Ontario.
1964	Ryder, R. A., W. B. Scott, and E. J. Crossman	Fishes of northern Ontario, north of the Albany River.
1964	Scott, W. B., and E. J. Crossman	Fishes occurring in the fresh waters of insular Newfoundland.
1964	Hubbs, C. L., and K. F. Lagler	Fishes of the Great Lakes region.
1967	Scott, W. B.	Freshwater fishes of eastern Canada. 2nd ed.
1967	Carl, G. C., W. A. Clemens, and C. C. Lindsey	The fresh-water fishes of British Columbia.
1969	Scott, W. B., and E. J. Crossman	Checklist of Canadian freshwater fishes with keys for identification.
1970	Paetz, M. J., and J. S. Nelson	The fishes of Alberta.
1970	Lindsey, C. C., and C. S. Woods (Ed.)	Biology of coregonid fishes.
1970	McPhail, J. D., and C. C. Lindsey	Freshwater fishes of northwestern Canada and Alaska.

INSTRUCTIONS ON PREPARING AND FORWARDING SPECIMENS FOR IDENTIFICATION

Maintaining up-to-date information on the distribution of freshwater fishes in Canada is an integral part of the activities of an ichthyologist or a department of fishes at a Natural History Museum or at certain universities. Such individuals or departments are interested in receiving preserved specimens of fishes from remote areas or from localities on the extremes of the known range of a species, as well as unidentifiable fishes thought to be new or strange in any area. The best ways of preparing specimens for shipment are as follows:

1. *Formalin preservation* — formalin is obtainable from most hardware stores, drug stores or farm supply agencies. One part of the fluid, as supplied, is diluted with nine parts of water. The fish is immersed in this solution as quickly after capture as possible and left there 5–7 days depending on size. Fish over 6 inches in length should be slit (2 one-inch slits, in lower right side of fish) in order to allow the preservative to enter the body cavity. After several days in this 10% formalin, the fish will be hard. It can then be removed, wrapped in a wet cloth, placed in some light but waterproof container such as a heavy plastic bag, plastic bottle, small tin with tight lid, packaged adequately for mailing, and mailed to the nearest interested institution or individual. In preparing the specimen, care should be taken to avoid, as much as possible, contact with the corrosive poisonous formalin or its fumes. The 10% solution will harden skin and the fumes can cause unpleasant nasal inflammation. Great care should be taken to protect the eyes from splashes.
2. *Other liquid preservation* — other liquids with high alcoholic content, such as rubbing alcohol or full strength liquor can be used. If placed in these fluids, specimens should be left longer before shipment and will not become hard as in formalin.
3. *Freezing* — specimens can be hard frozen, packed in dry ice (solid carbon dioxide) in an insulated container such as a picnic cooler. This method can be used only when delivery can be guaranteed in less than 3 days, otherwise the carrier will abandon the thawed, wet package and the specimens will be of no value if ever delivered. Frozen shipments are expensive, dangerous, and should be forwarded only after prior arrangement with the recipient. He should be given, by phone or telegram, such information as method of shipment, flight number, waybill number, date, place, and time of consignment to shipper.
4. *Salting* — fish can be preserved by packing the body cavity with salt, packing the specimens in salt in a waterproof container as above, and mailing for fast delivery. Also, fish can be immersed for several days in a strong brine solution (at least 1 pound of salt to 1 gallon of water), then proceed as with formalin or alcohol specimens. Body cavity must be opened to allow rapid entry of salt solution. If the fish is large, the head, the backbone in several segments, the fins, and skin from one side can be shipped after treatment.

Each lot of specimens from a different location or body of water should have with it a label. The label should be of the highest quality paper or fibre, and the notations printed clearly in pencil (the fluids will remove ball point ink). Such information as precise location of capture, the major river of which the body of water is a part, distance to nearest feature readily found on a map, date of capture, name of collector is desirable. If possible, notice of date and method of shipment, method of preservation and the information on the labels should be sent separately to the addressee.

The following institutions maintain permanent research collections of fishes:

— Nova Scotia Museum, Halifax
— Laboratoire de Recherches, Service de la Faune du Québec, 5075 rue Fullum, Montreal 178
— Centre Biologique, Quebec City
— National Museums of Canada, Ottawa
— Royal Ontario Museum, Toronto
— Alberta Provincial Museum, Edmonton
— Institute of Animal Resource Ecology, University of British Columbia, Vancouver
— British Columbia Provincial Museum, Victoria.

In addition to the staffs of the above institutions, the following individuals could provide identifications or additional information, especially on local fauna:

— C. C. Lindsey, Dept. of Zoology, University of Manitoba, Winnipeg
— F. M. Atton, Saskatchewan Fisheries Laboratory, Saskatoon
— J. S. Nelson, Dept. of Zoology, University of Alberta, Edmonton
— Martin Paetz, Dept. of Lands and Forests, Edmonton
— J. D. McPhail, Dept. of Zoology, University of British Columbia, Vancouver 8.

OUTLINE OF A SPECIES ACCOUNT

Description

The same sequential arrangement is used throughout the book and, hopefully, will help the reader to find a particular measurement or meristic value. Except where specified otherwise, we have followed the methods of measurement outlined by Hubbs and Lagler (1964). One such exception is in the body length measurement. Instead of the standard length used by ichthyologists we have in most cases employed total length, i.e. snout to tip of tail, since we believe this measurement is most frequently used by fishery biologists, students, anglers, and commercial fishermen. Legal-size limits, where employed, are usually based on total length. We recognize the necessity of using standard length measurements for scientific studies but believe its use in this text would have imposed unnecessary restrictions on the reader. However, in certain cases (such as the mooneyes) where published measurements were available in percentage of standard length, we gave them in this way rather than converting them. Ichthyologists will still, of course, use a standard length, although there are a number of ways to take a "standard" length. When used herein by us, standard length means the length from the anteriormost part of the head to the posterior margin of the last whole vertebral centrum (which is also the last vertebra counted).

In tables throughout this text, the following abbreviations have been used: FL = fork length, SL = standard length, TL = total length.

Fin ray counts, vertebrae number, and other meristic data vary because of genetic and environmental influences. The total range of values for these characters is shown but, when possible, the number of specimens displaying a particular count is shown in parentheses immediately following the count. If a meristic value appears to vary from province to province, an attempt was made to show the range of values by province.

The descriptions are based, in the great majority of cases, upon the examination of Canadian specimens. Consequently much meristic and morphometric data are available on file in the ROM and, in addition to collections of preserved specimens, there are good representative collections of cleared and stained specimens and a large file of x-rays.

Colour

Emphasis is placed on colours of living fishes and wherever possible, colours of young and spawning fish are included when these differ markedly from normal adults.

Systematic notes

Discussions of taxonomic history, subspecific designations, problems concerning common names, and often hybridization (*see also Biology* section) are included here. Whenever possible an attempt has been made to include controversial aspects of the systematics of a species.

Distribution

Information on distribution is presented both in written form and on maps. So far as the Canadian distribution is concerned an attempt has been made to follow a consistent pattern, working from east to west, and south to north. Thus, Newfoundland, Nova Scotia, and Prince Edward Island will always appear before Manitoba, if included in the range of a particular species. Similarly the Northwest Territories will usually be mentioned last. In preparing the maps, it was deemed impractical to attempt to identify each dot. Round spots indicate the existence of a specimen in the collections of the Royal Ontario Museum or another institution such as the University of British Columbia or the National Museums of Canada, diamond-shaped spots represent literature references. In both cases emphasis has been placed on marginal or peripheral locality records in order to define the outer limits of range. For those especially interested, more detailed information for each distributional record is available from the master maps on file in the Department of Ichthyology and Herpetology, Royal Ontario Museum. The shaded portion represents the total range of the species. The insert maps represent the range of the species in North America, the northern hemisphere or the world, whichever is pertinent.

Biology

Again a sequential arrangement has been followed, commencing with spawning and egg characteristics, and proceeding through developmental rates, growth, habitat, food, predators, and parasites. For some species notes on hybrids appear here. Canadian studies have been emphasized whenever these exist and are known to us. It was surprising to us that so many species have been ignored by biologists, while other species have been studied, restudied, and studied again. We have tended to avoid reference to unpublished theses whenever possible. Comparative growth rates are provided whenever these were available. We have attempted to include in the tables, growth rates from different areas east to west, and north to south, to illustrate the differences over the whole of the range. It was not always possible to find all the growth rates for any species in the same length measurement nor to be sure in some cases what length the author intended. When available, the maximum known size and recent angler size record are included at the end of the discussion on growth. The reader is also advised to consult Carlander (1969), McPhail and Lindsey (1970), and pertinent regional texts for additional information and references.

The section on parasites is intended as a preliminary guide to the better-known studies on parasites of our freshwater fishes. It was prepared primarily by reference to the works of Bangham and co-workers; Lawler and co-workers; Price and Arai (1967); Sandeman and Pippy (1967); Hoffman (1967); and the many recent papers by Dechtiar (1965–1970).

Relation to man

The title is really self-explanatory. An attempt has been made to indicate how commercial species are caught, processed, and marketed; in some cases the poundage landed is also given. Sport or game fishes are also evaluated, when possible. Flavour and edibility are usually described. Special features such as marked reduction in numbers, excessive mortalities, or use as experimental animals are also included.

Nomenclature

We have provided a partial synonymy only, giving emphasis to Canadian references and to those for international waters such as the Great Lakes and Lake Champlain. It was our intention to list most of the other scientific names used in Canadian literature to describe a species, so that early historical literature might be more readily interpreted. Thus, a reader is enabled to discover that the deepwater sculpin, now called *Myoxocephalus quadricornis,* appeared in the literature, just a few years ago, as *Triglopsis thompsoni,* and that these two names apply to the same species. We have not attempted to trace all the combinations of names used as subspecies of the various fishes nor to follow the shifting attitude toward the use of *i* or *ii* endings on scientific names.

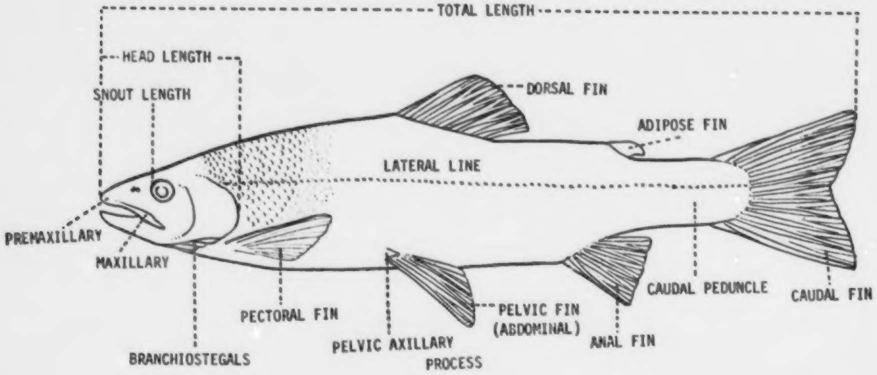
The common and scientific names used are in general accord with those recommended by the American Fisheries Society in its recent Special Publication No. 6, *A list of common and scientific names of fishes from the United States and Canada* (1970). We are indebted to Vianney Legendre, Director, Research Laboratory of the Quebec Wildlife Service, and his colleagues for the French common names.

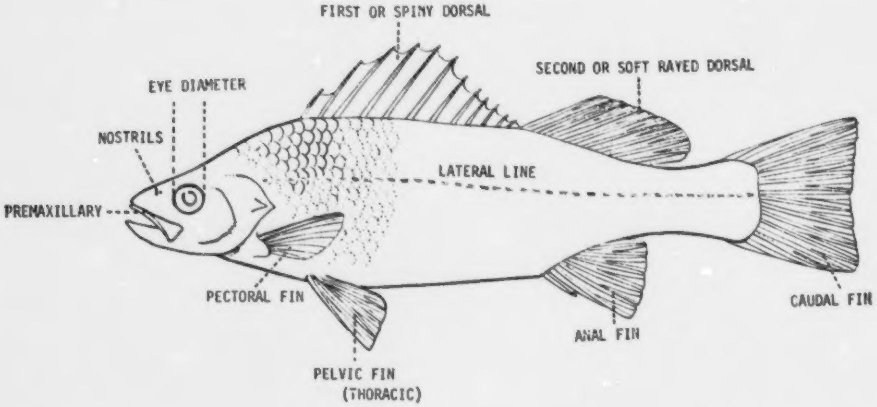
Suggested reading

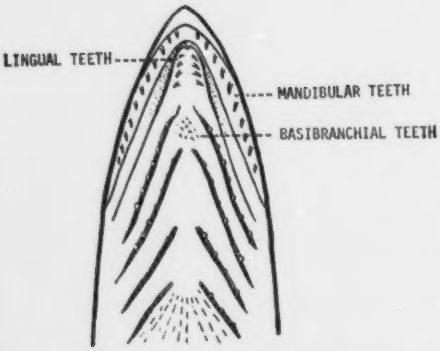
For further information about the family or individual species, *see* the section entitled Suggested Reading at the end of each family account.

SKETCHES OF ANATOMICAL FEATURES

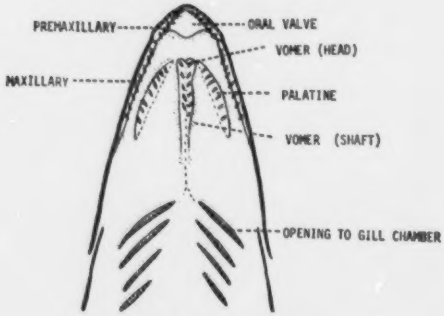
SKETCHES OF ANATOMICAL FEATURES


TOTAL LENGTH
HEAD LENGTH
SNOUT LENGTH
DORSAL FIN
ADIPOSE FIN
LATERAL LINE
PREMAXILLARY
MAXILLARY
CAUDAL PEDUNCLE
CAUDAL FIN
PECTORAL FIN
PELVIC FIN (ABDOMINAL)
ANAL FIN
PELVIC AXILLARY PROCESS
BRANCHIOSTEGALS

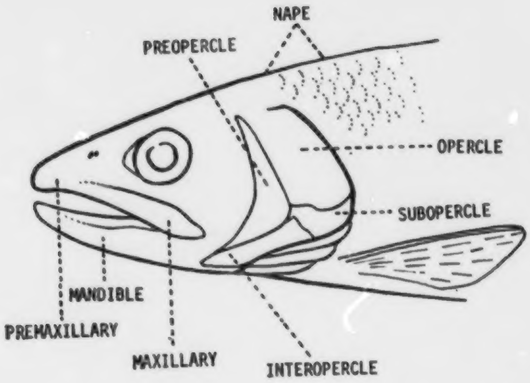

FIRST OR SPINY DORSAL
SECOND OR SOFT RAYED DORSAL
EYE DIAMETER
NOSTRILS
LATERAL LINE
PREMAXILLARY
PECTORAL FIN
CAUDAL FIN
ANAL FIN
PELVIC FIN (THORACIC)

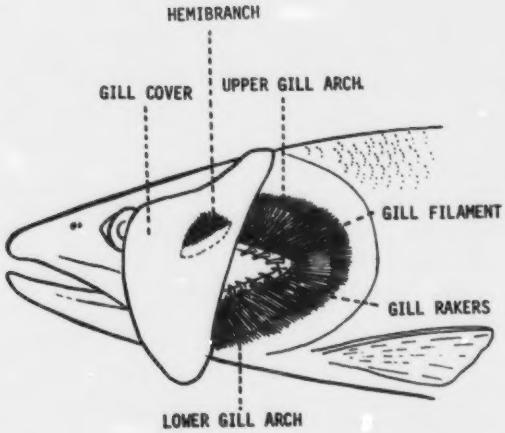

LINGUAL TEETH
MANDIBULAR TEETH
BASIBRANCHIAL TEETH

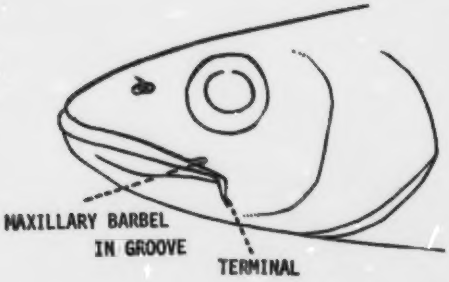
FLOOR OF MOUTH AND PHARYNX


PREMAXILLARY
ORAL VALVE
VOMER (HEAD)
MAXILLARY
PALATINE
VOMER (SHAFT)
OPENING TO GILL CHAMBER

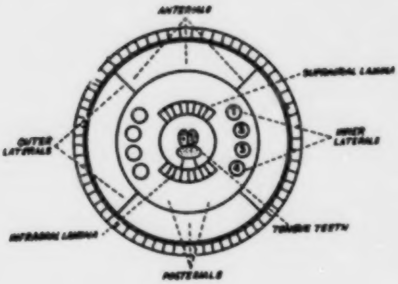
ROOF OF MOUTH AND PHARYNX


NAPE
PREOPERCLE
OPERCLE
SUBOPERCLE
MANDIBLE
PREMAXILLARY
MAXILLARY
INTEROPERCLE

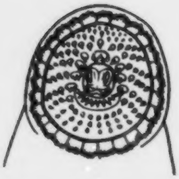

HEMIBRANCH
GILL COVER
UPPER GILL ARCH
GILL FILAMENT
GILL RAKERS
LOWER GILL ARCH


MAXILLARY BARBEL
IN GROOVE
TERMINAL

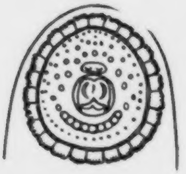
MAXILLARY BARBELS


ANTERIALS
SUPRAORAL LAMINA
OUTER LATERALS
INNER LATERALS
INFRAORAL LAMINA
TONGUE TEETH
POSTERIALS

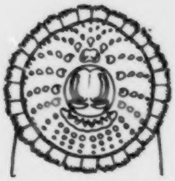
SCHEMATIC REPRESENTATION OF LAMPREY BUCCAL FUNNEL SHOWING GROUPS OF TEETH



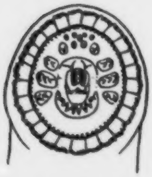
Chestnut lamprey



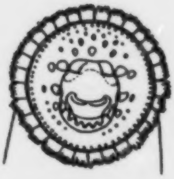
Northern brook lamprey



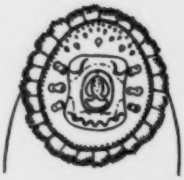
Silver lamprey



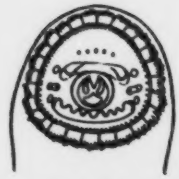
River lamprey



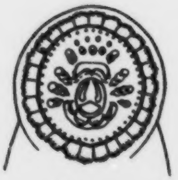
Arctic lamprey



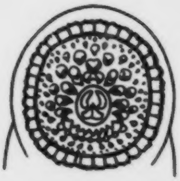
American brook lamprey



Western brook lamprey

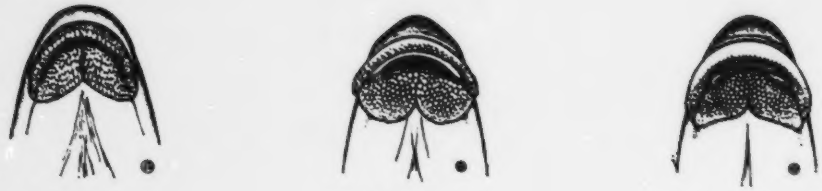


Pacific lamprey

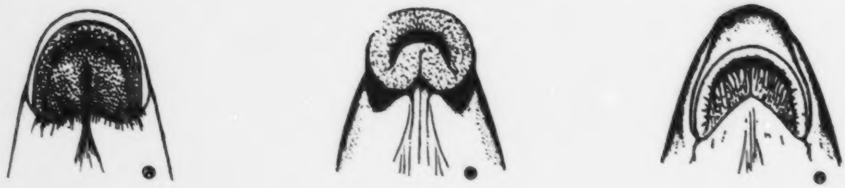


Sea lamprey

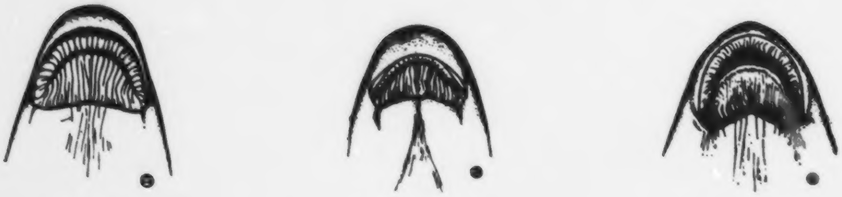
LAMPREY BUCCAL FUNNELS



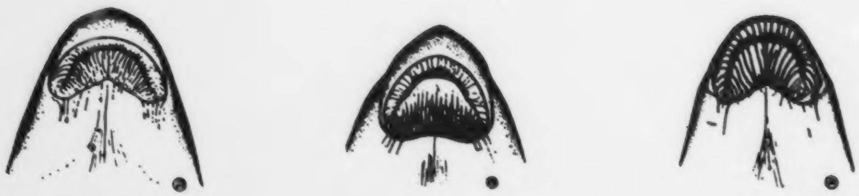
White sucker Bridgelip sucker Mountain sucker



Largescale sucker Northern hog sucker Silver redhorse



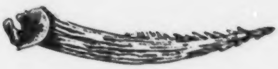
River redhorse Black redhorse Golden redhorse



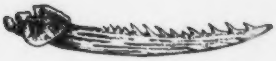
Copper redhorse Shorthead redhorse Greater redhorse

MOUTHS OF SOME SUCKERS

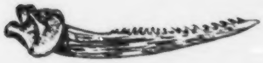
Black bullhead (*left*)



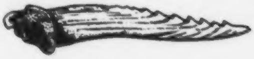
Yellow bullhead (*left*)



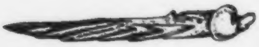
Brown bullhead (*left*)



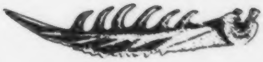
Channel catfish (*left*)



Stonecat (*left*)

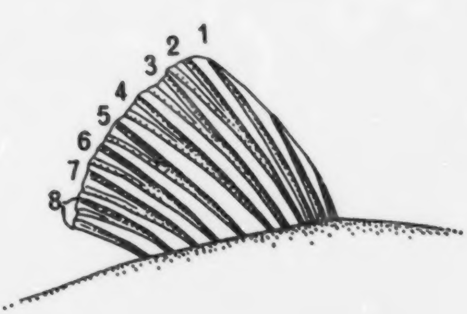


Tadpole madtom (*right*)

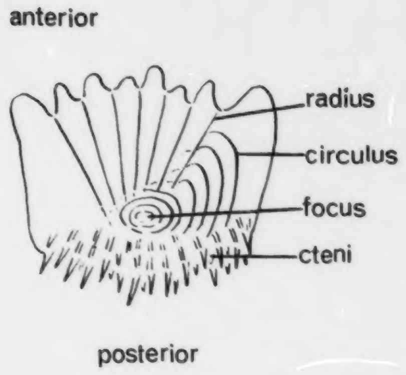


Brindled madtom (*right*)

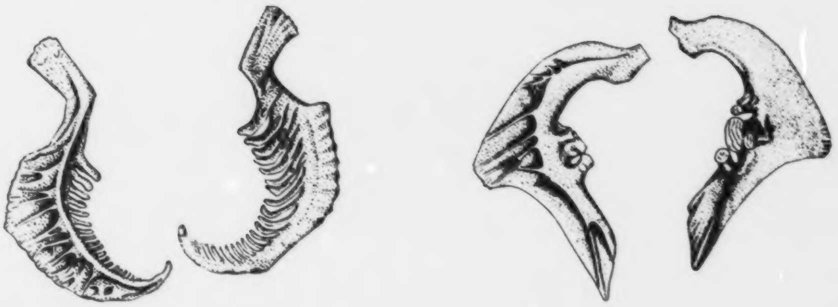
PECTORAL SPINES OF CATFISHES



ENUMERATION OF DORSAL AND ANAL FIN RAYS

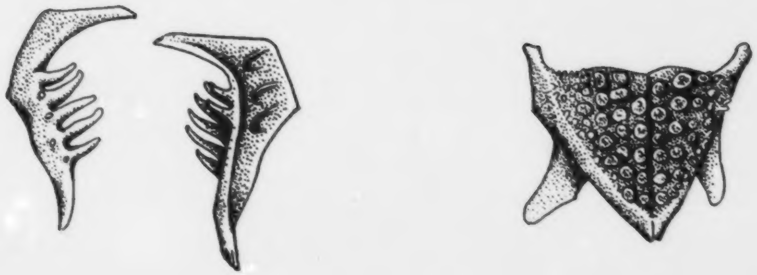

anterior
radius
circulus
focus
cteni
posterior

PARTS OF A CTENOID SCALE



White sucker

Carp



Creek chub

Freshwater drum

PHARYNGEAL ARCHES WITH TEETH

KEY TO THE FAMILIES OF FISHES OCCURRING IN THE FRESH WATERS OF CANADA

KEY TO THE FAMILIES OF FISHES OCCURRING IN THE FRESH WATERS OF CANADA

1 Mouth without true jaws, instead a circular, suctorial disc; no paired fins; 7 pairs of gill openings. .... LAMPREYS, family Petromyzontidae (p. 36)

Mouth with true jaws (i.e., upper and lower jaws present); with paired fins; opercles (or gill covers) overlying gills 2

2 Upper and lower lobe of caudal (tail) fin, when present, of about equal size; body covering of overlapping scales or naked; no barbels before mouth; skeleton bony 3

Upper lobe of caudal (tail) fin distinctly larger than lower lobe; mouth inferior; snout well developed; 5 rows of bony plates arranged longitudinally along body; 2 pairs of barbels before mouth. .... STURGEONS, family Acipenseridae (p. 78)

3 Under surface of head, between lower jaws, with strong bony plate ("gular" plate). .... BOWFINS, family Amiidae (p. 111)

Under surface of head (i.e., between the lower jaws) soft and not protected by large bony plate 4

4 Pelvic fins present 5

Pelvic fins absent; body cylindrical, long, and snakelike; dorsal, caudal, and anal fins continuous; no distinct caudal fin. .... EELS, family Anguillidae (p. 623)

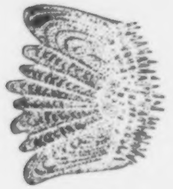
5 Adipose fin present 6

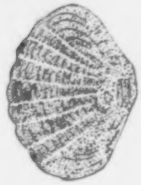
Adipose fin absent 11

6 Body scaleless; strong pectoral and dorsal spines; long barbels about mouth. .... CATFISHES, family Ictaluridae (p. 588)

Body scaled; no strong spines in fins; no long barbels about mouth 7

7 Pectoral fin overlaps anterior pelvic base; scales (weakly) ctenoid. ....
TROUT-PERCH, family Percopsidae (p. 677)

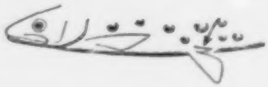




Pectoral fin tip never reaches anterior base of pelvic fin; scales cycloid 8

8 Pelvic axillary process absent. .... SMELTS, family Osmeridae (p. 306)

Pelvic axillary process present 9



9 Mouth usually large, extending to middle of eye or beyond; teeth strong. .. .... SALMONS AND TROUTS (Salmoninae), family Salmonidae (p. 138)

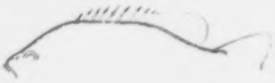
Mouth usually small and not extending beyond middle of eye; teeth weak or absent 10

10 Dorsal fin shorter than head, dorsal rays 16 or fewer. .... WHITEFISHES, CISCOES (Coregoninae), family Salmonidae (p. 138)

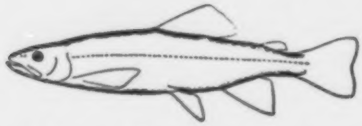
Dorsal fin base longer than head, fin very high, rays 17 or more. .... GRAYLING (Thymallinae), family Salmonidae (p. 138)

11 Soft (or second) dorsal fin preceded by 2–10 isolated, sharp spines or by a separate spiny dorsal of 4 slender and soft, inconspicuous spines; small fishes, less than 6 inches long 25

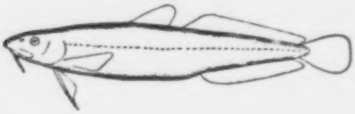
Soft (or second) dorsal fin not preceded by isolated spines, but spines, if present, joined together by fin membrane; small and large fishes 12

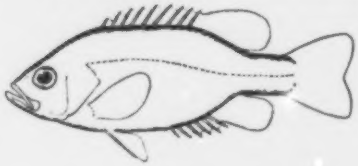


12 Pelvic fins abdominal and well developed; one rayed dorsal fin; all fins soft rayed and without spines 13



Pelvic fins thoracic or jugular, often reduced; dorsal fin usually 2, but if only 1, the anterior portion composed of well-developed spines 20

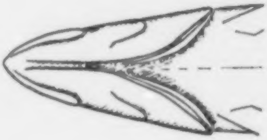




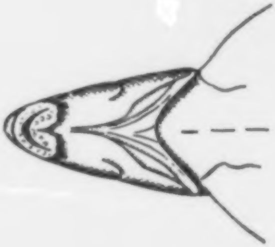
13 Body covered with thick, hard, glossy rhomboid scales. .... GARS, family Lepisosteidae (p. 101)

Body normally scaled or with scattered prickles 14

14 Gill membranes not attached to isthmus (gill openings wide) 15



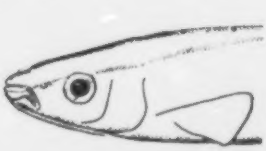
Gill membranes broadly joined to isthmus (gill openings narrow) 18



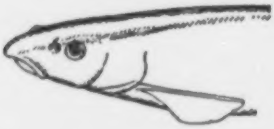
15 Head with some scales; body elongate; spotted, barred, or dark coloured 16

Head without scales; body laterally compressed; silvery 19

16 Upper jaw protractile. .... **KILLIFISHES,** family Cyprinodontidae (p. 630)



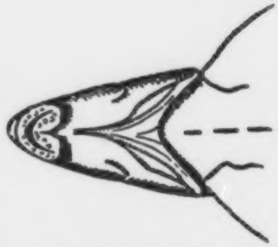
Upper jaw not protractile. 17



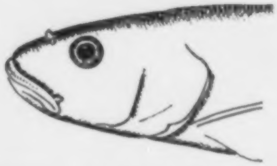
17 Jaws well developed; teeth strong; caudal fin forked. PIKES, family Esocidae (p. 346)

Jaws short; teeth small; caudal fin rounded. MUDMINNOWS, BLACKFISH, family Umbridae (p. 337)

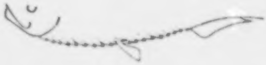
18 Lips usually thick and mouth inferior (except *Ictiobus* where it is oblique and with normal lips; however, in *Ictiobus* the long dorsal fin has over 28 rays, and the longest unbranched ray is not a serrate, heavy spine, thus separating it from the 2 cyprinids with long dorsal rays, *Cyprinus* and *Carassius*); pharyngeal teeth numerous and in 1 row, comblike; swim bladder of 2 or 3 chambers. SUCKERS, family Catostomidae (p. 523)



Lips thin, mouth seldom inferior (except in *Rhinichthys* where scales are minute and much smaller than in suckers); if dorsal fin long, no more than 22 rays and second unbranched element a heavy, serrate spine; pharyngeal teeth in 2 or 3 rows, fewer than 9 per side; swim bladder of 2 chambers. MINNOWS, family Cyprinidae (p. 376)



19 Lateral line absent; teeth absent; belly with sharp, pointed scales (scutes); dorsal fin situated over pelvic fins and well in advance of anal fin; never more than 23 anal rays. HERRINGS, family Clupeidae (p. 117)



Lateral line present, at times indistinct; teeth present; no sharp, pointed scales on belly, scales smooth; dorsal fin over anal fin and well behind pelvic fins; always more than 25 anal rays. MOONEYES, family Hiodontidae (p. 326)

20 Body plated, naked, or with prickles; pectoral fins large and conspicuous. SCULPINS, family Cottidae (p. 817)

Body scaled (scales small and somewhat embedded in Gadidae); pectoral fins of moderate size, not conspicuous 21

21 Chin with small but distinct median barbel. CODS, family Gadidae (p. 640)

Chin without small median barbel 22

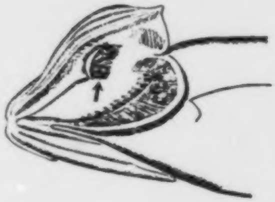
22 Anal spines 1 or 2 23

Anal spines 3 or more 24

23 Second anal spine strong, stout, and conspicuously larger than first; lateral line extending onto caudal fin. .... DRUMS, family Sciaenidae (p. 811)

Second anal spine slender and not conspicuously larger than first; lateral line not extending onto caudal fin. .... PERCHES, family Percidae (p. 751)

24 Opercle with a spine; 3 anal spines; hemibranch well developed and obvious. .... TEMPERATE BASSES, family Percichthyidae (p. 683)



Opercle without a spine; 3 or more anal spines; hemibranch concealed or absent. .... SUNFISHES, family Centrarchidae (p. 699)

25 Strong pelvic spines present; first dorsal spine arising well in advance of anal fin origin. .... STICKLEBACKS, family Gasterosteidae (p. 656)

Pelvic fins without spines; first dorsal spine arising approximately over anal fin origin; slender silvery fishes. .... SILVERSIDES, family Atherinidae (p. 651)

SPECIES ACCOUNTS

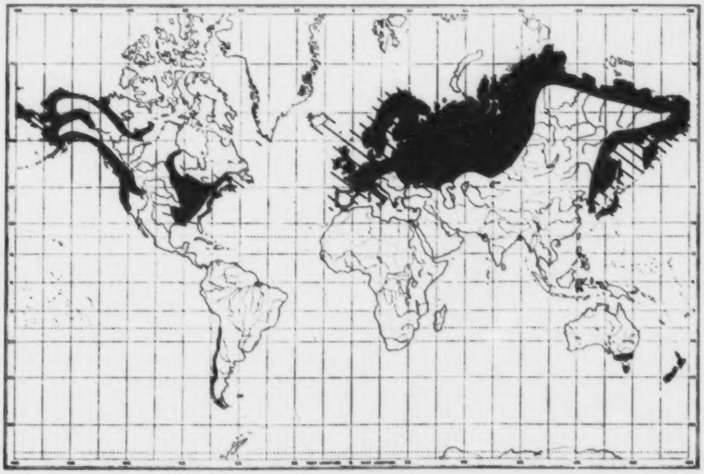
THE LAMPREYS — Order Petromyzontiformes

Body naked, eel-like; with round, suctorial mouth armed with horny teeth, often sharp, on funnel and tongue. A long dorsal fin, often of two parts; no paired fins and no paired fin girdles. No bone in the skeleton; skull cartilagineous; vertebrae without centra. A single median nasal opening between the eyes, not connected to the pharynx. Seven pairs of gills in the form of gill pouches, each pouch opening to the outside by an individual opening. Muscle blocks or myotomes not divided by a horizontal septum into dorsal and ventral parts. Characteristic metamorphosis from blind, toothless larva or ammocoete to toothed, sighted adult in 1–4 years.

A single living family, Petromyzontidae, and no reliable fossil representative other than the specimen of *Mayomyzon pieckoensis* described by Bardack and Zangerl (1968) from the Pennsylvanian of Illinois.

LAMPREY FAMILY—Petromyzontidae

There are about 30 species in 8 genera of living lampreys. Five genera *Caspiomyzon, Entosphenus, Ichthyomyzon, Lampetra*, and *Petromyzon* occur in the northern hemisphere whereas *Exomegas, Geotria*, and *Mordacia* occur in the southern hemisphere. They are generally distributed in temperate marine and fresh water, some anadromous. Life span from 2 to 5 years, involving metamorphosis. The time to metamorphosis varies with species, from 1 to 4 or 5 years. All larvae or ammocoetes live in fresh water, usually in burrows in the soft bottom of streams and lakes. Eyes are present in the ammocoetes, but are covered and sightless; teeth are absent and the mouth has an oral hood. After transformation, the adult possesses the characteristic fringed, well-toothed, circular, suctorial mouth. Many species are externally parasitic, attaching themselves to other fishes with the suctorial mouth and using a rasping tongue to break the surface of the host in order to consume the blood slowly. Some freshwater species that are not parasitic, mate and spawn soon after transformation, and then die.

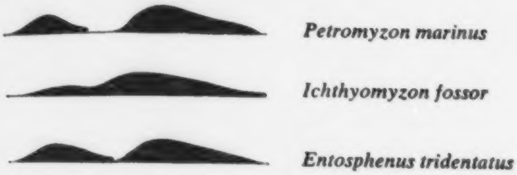


World Distribution of the Lampreys

KEY TO SPECIES

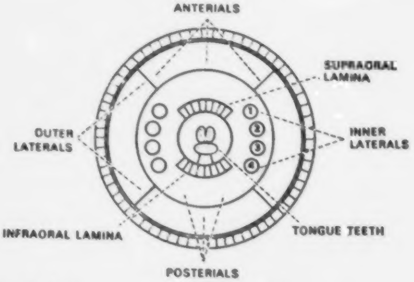
(This key is intended only for transformed individuals. The identification of immature lampreys (larvae or ammocoetes, with an oral hood) requires much more detail.)

1 Dorsal fin composed of 2 obvious lobes; lobes separated or joined by very low and inconspicuous connection 2

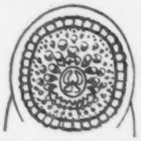

Petromyzon marinus
Ichthyomyzon fossor
Entosphenus tridentatus

Dorsal fin single but notched; notch never reaching dorsal surface of body 7

2 Supraoral teeth on broad curved bar (lamina) 3

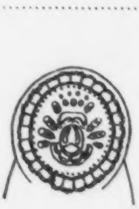

ANTERIALS
SUPRAORAL LAMINA
OUTER LATERALS
INNER LATERALS
1
2
3
4
INFRAORAL LAMINA
TONGUE TEETH
POSTERIALS

Supraoral teeth not on broad curved bar (lamina) but consisting of a single, median, large, bicuspid tooth, with pointed cusps; laterals 4, bicuspid, pointed cusps, trunk myomeres 67–74; parasitic; to 33.8 inches (860 mm) in length. .... SEA LAMPREY, *Petromyzon marinus* (p. 69)



3 Supraoral lamina with 2 lateral cusps, no median cusp.................................... 4

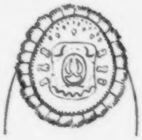
Supraoral lamina with 3 prominent, sharp cusps, one median; lateral teeth 3 or 4 with at least the middle 2 on each side tricuspid, others bicuspid, or tricuspid; semicircular row of small teeth below infraoral bar; trunk myomeres usually 64–74; parasitic; to 26.8 inches (680 mm) in length. ....
.... PACIFIC LAMPREY, *Entosphenus tridentatus* (p. 42)



4 Inner lateral teeth 3, all bicuspid, or at least middle one on both sides bicuspid 5

Inner lateral teeth 3, at least middle tooth on both sides tricuspid 6

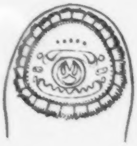
5 Inner lateral teeth prominent, bluntly pointed, all bicuspid; teeth above supraoral lamina prominent, pointed; tongue with sharp teeth *and* trunk myomeres usually 64–70, nonparasitic, to 7.4 inches (187 mm), Great Lakes and eastward. ....
.... AMERICAN BROOK LAMPREY, *Lampetra lamottei* (p. 62)



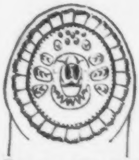
or

trunk myomeres usually 68–74, parasitic?; at least to 11.8 inches (300 mm), Great Slave Lake and northwestward. ....
.... ARCTIC LAMPREY, *Lampetra japonica* (p. 58)

Inner lateral teeth poorly defined, knoblike, some may be unicuspid; teeth above supraoral bar (anterials), if apparent, very small and peglike; no sharp teeth on tongue; trunk myomeres 60–67; non parasitic; length to 6 inches (154 mm). ....
.... WESTERN BROOK LAMPREY, *Lampetra richardsoni* (p. 65)

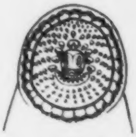


6 Teeth above supraoral lamina (anterials) prominent and sharp; sharp teeth on tongue; trunk myomeres 60–71; parasitic; length to 12 inches (311 mm). ....
.... RIVER LAMPREY, *Lampetra ayresi* (p. 55)



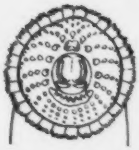
Teeth above supraoral lamina (anterials), if apparent, very small and peglike; no sharp teeth on tongue; trunk myomeres 60–67; nonparasitic; length to 6 inches (154 mm). ....
.... WESTERN BROOK LAMPREY, *Lampetra richardsoni* (p. 65)

7 Lateral teeth all unicuspid 8

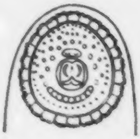


At least 1 or more bicuspid, inner, lateral teeth on each side; supraoral a single, sharp, bicuspid tooth; trunk myomeres usually 51–54; parasitic; to 15 inches (380 mm) in length. ... . CHESTNUT LAMPREY, *Ichthyomyzon castaneus* (p. 46)

8 Supraoral usually a single, bicuspid tooth (1 cusp rarely doubled), cusps sharp; infraoral lamina with prominent triangular cusps; diameter of sucking disc greater than that of branchial region; trunk myomeres 47–55; parasitic; length to 13 inches (328 mm). .... SILVER LAMPREY, *Ichthyomyzon unicuspis* (p. 52)



Supraoral a single, weak, bicuspid tooth, cusps knob-like; infraoral lamina with low, knob-like cusps; diameter of sucking disc less than that of branchial region; trunk myomeres usually 51–58; nonparasitic; length to 6 inches (150 mm). .... NORTHERN BROOK LAMPREY, *Ichthyomyzon fossor* (p. 49)



Entosphenus tridentatus
(27 inches, 682 mm)

Ichthyomyzon castaneus
(15 inches, 380 mm)

I. fossor
(5.9 inches, 150 mm)

I. unicuspis
(12.9 inches, 328 mm)

The nine species of lampreys
in Canada.
Known maximum length in Canada
is given in parentheses after the name.

Lampetra ayresi
(12.2 inches, 311 mm)

L. japonica
(16.2 inches, 411 mm)

L. lamottei
(8 inches, 203 mm)

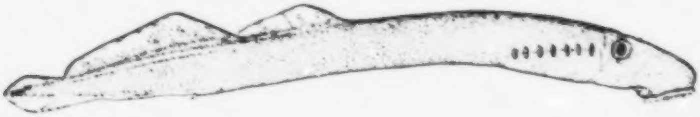
L. richardsoni
(6 inches, 154 mm)

Petromyzon marinus
(34 inches, 865 mm)

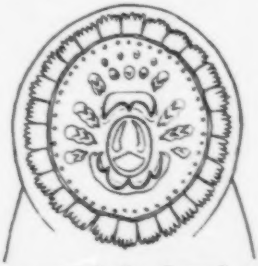
41

PACIFIC LAMPREY

Entosphenus tridentatus (Gairdner)



Description The parasitic Pacific lamprey is an elongate, almost cylindrical animal, round in cross section from head to dorsal fins, beyond this point gradually more laterally compressed. Usual length to 26.8 inches (680 mm). In transformed individuals the short, jawless head has a large, nearly circular, buccal funnel fringed with leathery, marginal appendages called fimbriae.



The inner part of the funnel around the mouth has many series of sharp teeth; supraoral lamina, or bar, of 3 large cusps, infraoral lamina with 5–8 cusps, 3 pairs of inner lateral teeth some tricuspid, scattered bicuspid and single teeth, and a ring of small, marginal teeth. The tongue is also armed with sharp teeth. Beyond the mouth there are 13–16 velar tentacles. The eyes are small and high, with a median, single nostril between and ahead, and 7 pairs rounded, lateral gill openings behind. Fins: dorsals 2, separated by complete cleft; first dorsal low, flat to rounded; second dorsal longer, higher, rounded to pointed; small, spade-shaped caudal confluent with second dorsal and anal; anal very low, inconspicuous; no paired fins or their skeletal supports. No scales or denticles, skin smooth and leathery; no lateral line but 58–74 vertical myomeres obvious externally, at least on small individuals. Skeleton cartilagineous* throughout, no vertebrae, notochord persists.

Colour Overall colour of transformed adults blue-black to dark brown, lighter below, no pattern, burrowing ammocoetes paler. Teeth usually yellow to orange in life.

Systematic notes The populations were, at one time, split into two groups (Creaser and Hubbs 1922) as *E. t. tridentatus* Richardson, from Columbia River to Alaska, and *E. t. ciliatus* Ayres, from the Klamath River southward. This division on basis of myomere number no longer holds.

A major work, edited by Hardisty and Potter (*see Suggested Reading*), contained a paper by Hubbs and Potter that reduced *Entosphenus* to a subgenus of *Lampetra*.

Distribution Restricted to the Pacific coast and coastal islands of North America, from Unalaska Island (Aleutians) to Baja California. In Asia, at least as far south as the Yuhutu River, Hokkaido, Japan. Penetrating all major rivers, often to headwaters, including the Columbia River in British Columbia and the Fraser–Thompson up stream as far as Shuswap Lake. For detailed distribution in British Columbia *see* Carl et al. (1967). First recorded from Canada in 1891 (Clemens and Wilby 1961).

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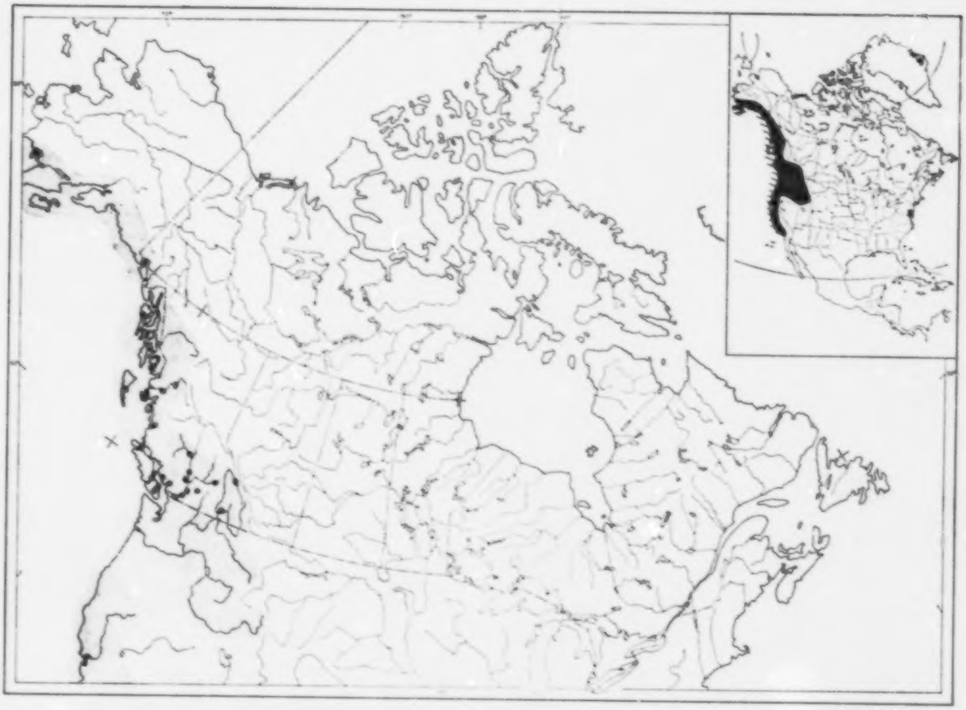
*The alternative spelling for "cartilaginous" has been used throughout the book.



Biology The spawning migration from the sea of adult Pacific lamprey usually begins during the period July to September. These lampreys are not sexually mature at this time and spend from October to the following March hidden under stones. Feeding appears to cease during early stages of the upstream migration. Nest building and spawning take place from April to July (Pletcher 1963). The lampreys move up rivers and streams, sometimes several hundred miles, to the headwaters, where they spawn in sandy gravel at the upstream edge of riffles. Moderately strong swimming ability and capacity to cling to rocks, dams, and fishways by means of the suctorial disc, enable them to surmount most obstacles. The males may arrive first, and both sexes dig the shallow nest 21–23 inches (533–584 mm) in diameter with body movements and by moving stones with the suctorial disc. The female attaches to a rock and orients across the nest, the male carries out a type of prespawning courting called "gliding–feeling" by moving or rubbing along the body of the female posterior to anterior with slight contact of the disc. When the male reaches the head of the female he attaches to it, coils around the female, eggs and sperm are emitted together, the fertilized eggs fall to the nest, are adhesive for 2 hours and cling to stones in the nest. A pair observed for 5 hours deposited 100–500 eggs regularly every 2–5 minutes. In the interval they continued nest building, which covers the eggs. Mean calculated egg number is 34,000 but can go as high as 106,000 in a 16-inch (406-mm) female. Eggs are oval, 1.06–1.09 mm wide and 1.12–1.24 mm long (Pletcher 1963). Most eggs are laid over a period of 12 hours. Males spawn with more than one female in different nests (Pletcher 1963). The adults do not migrate downstream and usually die 1–14 days after spawning. In certain landlocked populations living adults were found as late as September (Carl 1953). Eggs hatch in

2–3 weeks (19 days at 59° F (15° C)) as ammocoetes have been seen as early as June 27 (Carl 1953).

The ammocoetes, pale brown in colour, with a fleshy, toothless, oral hood instead of a sucker disc, mere fin folds, and undeveloped eyes, burrow into the mud downstream from the nest. Here they spend a maximum of 5 or 6 years. At transformation the animal moves out of the burrow. The many features of the adult, which enable it to lead a parasitic life, have developed, and large numbers move downstream in late summer during flood conditions, eventually reaching the sea or a lake. Apparently large numbers of incompletely transformed individuals accompany the movement of fully transformed lampreys (Applegate and Brynildson 1952). There are landlocked populations over the whole of the range that metamorphose and remain in fresh water to prey on freshwater fishes throughout their adult life (Coots 1955). Dwarf races are known to occur in certain rivers (Carl et al. 1967). The greater percentage move down to the sea or to river estuaries where, in the spring and summer following downward migration, they begin a parasitic life and spend 12–20 months as parasites before migrating upstream to spawn. There are populations of landlocked, nonparasitic Pacific lampreys known in Oregon and California (Hubbs and Miller 1948).

Minute when hatched, ammocoetes grow to about 0.4 inches (10.1 mm) in the first year. Age–total length relation for Pacific lamprey ammocoetes in the Thompson and Nicola rivers was calculated by Pletcher (1963) to be as follows:

Age (*years*)	TL(*mm*)	
	Mean	Range
0	17.5	0.2–21
1	39.0	26–49
2	52.5	40–62
3	67.5	56–75
4	78.5	70–83
5	97.0	74–118

If ammocoete life is 5 or 6 years, then total life span is at least 7 years. They are usually about 4.8–12.0 inches (122–303 mm) at transformation, an average of 21.2 inches (537 mm) total length when migrating inward from the sea, and attain a maximum length of 27 inches (682 mm) (Carl et al. 1967). The landlocked populations apparently rarely exceed 8 inches (202 mm) in length (Carl 1953).

As an external parasite, the Pacific lamprey lives on the blood and fluids of fish and other marine vertebrates. By means of the suctorial disc and disc teeth they attach themselves, usually to the side or undersurface of fishes. The toothed tongue rasps through scales and skin, and the fluids are consumed. This type of feeding is facilitated by the production of an anticoagulating agent that prevents the host's blood from solidifying. When the disc is attached to a host, oxygen-bearing water is pumped both in and out through the gill openings.

The Pacific lamprey and other lampreys do not apparently have many predators; they appear only infrequently in the stomach contents of other animals. On rare occasions they have been found in the stomachs of fur seals and sperm whales, and may have been on a host fish when it was consumed by the whale (Pike 1951). Experiments (Pfeiffer and Pletcher 1964) indicated that their low incidence in the diet of salmonines may be the result of distasteful secretions of granular or club cells in the skin. Salmonines in captivity would eat skinned Pacific lampreys but not the isolated skin. The Pacific lamprey probably competes for food with the other Pacific coast parasitic lampreys *Lampetra ayresi* and *L. japonica*, as well as for suitable spawning grounds with these and *L. richardsoni*.

The incidence of parasites in Pacific lampreys is unusually low. At Lakelse Lake 6 out of 10 lampreys examined were infected by only two parasites, *Eustrongylides* sp. and *Phyllobothrium* sp., both of which occur in their hosts and from which they probably got them (Bangham and Adams 1954).

Relation to man This and other parasitic lampreys usually bear only an indirect relation to man as a result of the potential destruction of their hosts. Egocentric man considers this predation destructive only when the host is a species that he favours for food or sport. The only known use of this lamprey as food is that reported for British Columbia Indians who for centuries have used it smoked, sun-dried, or salted. Indians on the Skeena and Fraser rivers line salmon dipnets with finer webbing to scoop lampreys from the river's canyon wall. A few people, recently arrived from Europe, catch them at Alberni with hooks attached to long poles. The ammocoetes are used as bait by trout fishermen, and some commercial fishermen say they are the best bait for sturgeon in the Fraser River (Pletcher 1963). A small, commercial fishery for this species took place, after 1941, at the falls of the Willamette River in Oregon. For some years 200 tons were taken annually for reduction (Pike 1953).

It is known that the landlocked population in Cowichan Lake, B.C., was considerable, that as many as three lampreys were found on one trout, and that 8 out of 10 game fish bore fresh or old scars (Carl 1953). A survey of predation on Pacific salmon showed it varied between species, more important for sockeye than for pinks. Williams and Gilhousen (1968) calculated that, for one particular stock of sockeye (Adams River) seen at the Fraser River mouth, as a consequence of predation of Pacific lamprey, 1.8% of the whole population and 37% of those most severely wounded by lampreys would die during upstream migration. As high as 76% of the rainbow trout in impounded Elsie Lake near Alberni showed scars of this lamprey (Pletcher 1963). There is no way of calculating the destruction of fishes by this lamprey in the open ocean. Marks of the teeth and disc of this species have been found on 25–89% of finback, sei, blue, humpback, and sperm whales examined off the coast of British Columbia (Pike 1951). Some scars showed obvious parasitism, others may indicate only transport of the lamprey by the host. In the western Pacific it was found that, for pink salmon in the Amur estuary, 21–44% of the fish examined were scarred by this species of lamprey. There were as many as five marks on 4.6% of the pinks. In coho salmon, 20% had marks of parasitism by Pacific lamprey (Birman 1950).

Nomenclature

Petromyzon tridentatus	— Gairdner (MS) *in* Richardson 1836: 293 (type locality Falls of Walamet, now Willamette, Oregon)
Lampetra tridentata	— Green 1891: 32
Entosphenus tridentatus tridentatus	— Creaser and Hubbs 1922: 10
Entosphenus tridentatus (Richardson)	— Vladykov and Follett 1958: 47
Lampetra tridentata (Gairdner)	— Scott and Crossman 1967: 3

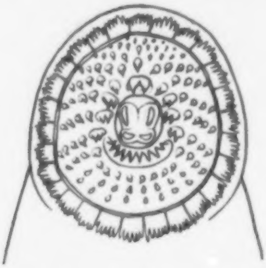
Etymology *Entosphenus* — within wedge, after the wedge-shaped tongue tooth; *tridentatus* — three-toothed, since many of the teeth have 3 cusps.

Common Names Pacific lamprey, sea lamprey, three-toothed lamprey, tridentate lamprey. French common name: *lamproie du Pacifique*.

CHESTNUT LAMPREY

Ichthyomyzon castaneus Girard

Description The chestnut lamprey is a small, parasitic lamprey with a cylindrical body to the dorsal fins where it becomes laterally compressed. In mature males the body is deeper over the whole length than that of immature lampreys. In the branchial region the body of the mature male is deeper and greater in cross section than even the mature female. The mature female differs from the immature largely in the swelling of the egg-filled abdominal section of the body (Hall 1963). Usual length to 14.9 inches (380 mm). In transformed individuals, the short head terminates in a circular, buccal funnel fringed with fimbriae. Oral disc not noticeably greater in diameter than branchial area, length equal to 5–9% of total length.

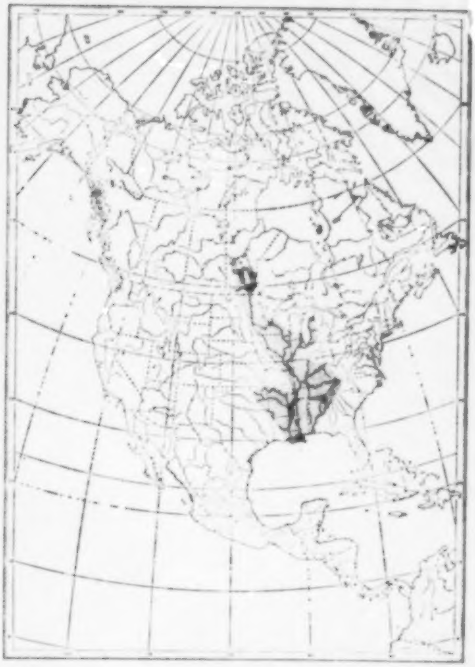


The inner surface of funnel is armed with many, strong, slender, sharp, curved teeth; supraoral lamina a single, bicuspid or tricuspid tooth; infraoral lamina a broad, curved bar with 6–11 sharp cusps; inner lateral (or circumoral) teeth 4, usually bicuspid sometimes tricuspid; several rows of unicuspid anterial (or maxillary labial) teeth; several rows of smaller, unicuspid posterial (or mandibular labial) teeth; marginal ring not obvious. Tongue teeth on paired plates, sharp but not large. Eyes small, high, with single median nostril ahead, 7 pairs of lateral gill openings behind. Fins: first and second dorsals connected, very shallow notch between, referred to as single dorsal, first dorsal lower, flat to rounded, very little distinction in height of first dorsal and second dorsal in mature males, second dorsal higher shallow curve, second dorsal connected to short, round caudal; "anal fin swelling" of the mature male is as prominent as, or more prominent than, that of the mature female; no paired fins or supports. No scales, skin smooth, leathery; no lateral line in usual position but 51–54 trunk myomeres in adults. No vertebrae, skeleton cartilagineous, notochord persists. *See* illustration p. 41.

Colour The specific name refers to chestnut colour but more usually the adults are dark grey to olive (Cross 1967) or yellow-brown above and lighter below; no obvious pattern. Adults become blue-black at spawning time. The ammocoetes are generally paler.

Systematic notes This species was long grouped by many authors with the silver lamprey, *I. unicuspis* of which it is a probable derivative. This was largely the result of working with material from south of the Great Lakes where the two occur together and where they may intergrade to a slight degree. The southern brook lamprey, *I. gagei*, is looked upon as a dwarf, degenerative derivative of *I. castaneus*, as *I. fossor* is of *I. unicuspis*.

Distribution Restricted to central North America. Southeast from west-central Manitoba, south of the Great Lakes to western Michigan, through the eastern parts of the state, from North Dakota to Texas and Louisiana. North in the Alabama system of Mississippi and Alabama, west to a line through central Illinois and then east to Michigan.



In Canada it is known from Manitoba only, from lakes Manitoba and Winnipeg and the Red and Assiniboine rivers (Keleher and Kooyman 1957). In the area south of the Great Lakes it overlaps the distribution of *Ichthyomyzon unicuspis*, but the two species are separated in Manitoba.

Ernest Seton Thompson's 1898 record of this species from the Assiniboine River at Portage la Prairie is probably the earliest Canadian record.

Biology This largely stream-living lamprey spawns in rivers from early to mid-June but possibly as late as early July. The peak of activity is in mid-June. Almost nothing is available on the spawning activity of the chestnut lamprey. Hall (1963) reported seeing, during a single night, 8–10 spawners on one nest in 2 feet of moderately swift water, well hidden under a log. Nest building and spawning would seem to take place at night. The adults die soon after egg laying is completed.

Ammocoetes of the chestnut lamprey, unlike other species, apparently prefer areas of moderate current, stable bottom of sand and silt with light growth of *Chara*. Larger ammocoetes found in quiet backwater areas of black muck and silt were only in areas where rooted vegetation was dense.

The length of ammocoete life is unknown but presumed to be 5–7 years. Metamorphosis or transformation begins in August or September of their final ammocoete year at a total length of 3.6–4.0 inches (90–100 mm) and is completed in January. They may be briefly parasitic that fall. The adults are inactive over the winter and commence active predatory feeding the following spring. Adults in the Manistee River in June ranged from 3.3 to 5.9 inches (84–150 mm) total length. In March the adults varied from 3.3 to 4.7 inches (83–119 mm) total length with an average of 4.1 inches (105 mm). In October of that same year adult size ranged from 4.7 to 8.3 inches (120–212 mm) total length with the average at 6.8 inches (172 mm) total length. Maximum size appears to be less than 12 inches (305 mm) total length.

Adults are predaceous in streams from April to October but the greatest feeding activity is in July. The adults are inactive once more the following winter during commencement of sexual maturity. They mate, spawn, and die in June or July of the following year. The adult life span is a maximum of 18 months. At one time or another in any calendar year there may be three year-classes of adults present in a stream.

The habitat of the ammocoetes differs from that of the sea lamprey and other lampreys in that the ammocoetes of this species prefer firmer bottom in swifter water, or softer bottom and denser vegetation. Adult chestnut lampreys appear to inhabit the main course of moderate-sized rivers and are not found in the smaller tributaries. Marked lampreys in Michigan moved up and downstream 12 and 24 miles but did not move into lakes.

Food of filter-feeding ammocoetes of the chestnut lamprey is the minute invertebrates, and possibly plants, common to all lampreys. Desmids, diatoms, and protozoans predominate. The predaceous adults attack a wide range of stream fishes and, like other predaceous lampreys, rasp into the flesh, consuming body fluid and muscles. Size of prey alone seems to limit choice. Those fishes reported by Hall (1960) as attacked by this species were as follows: brook trout, brown trout, rainbow trout, northern pike, chain pickerel, carp, creek chub, white sucker, smallmouth buffalo, channel catfish, burbot, green sunfish, largemouth bass, and smallmouth bass.

The ammocoetes probably compete for their invertebrate food with the young of all stream fishes and, in Canada, possibly with ammocoetes of the silver lamprey, *I. unicuspis*, the only other lamprey that occurs with it. Similarly, the adults may compete with the silver lamprey for hosts although their adult habitat usually separates these two species.

The chestnut lamprey is often preyed on by such fishes as trouts, especially brown trout. The ammocoetes have been reported as the bulk of the diet of the burbot, at times.

Relation to man No records were seen of the use by man of this smaller species as food or of the ammocoetes as bait for other fishes.

The indirect relation to man, their parasitism of economically important species, is possibly negligible in Canada. This species is not abundant even where it occurs, and is only of moderate size. The wounds are shallow and it is unlikely they cause mortality in larger fishes.

Its habitat in middle-size streams and its size preclude it doing any significant harm to commercial fishes. It is relatively less lethal than the sea lamprey and the silver lamprey but in some areas it definitely destroys trout by its feeding. In a study in Michigan, 18–19% of the trout in a stream, and up to 35% of the trout over 7 inches (180 mm) long in the creel census, had been attacked by one or more lampreys. Larger fish survived attacks except those of the most prolonged period. Maximum time of attachment noted by Hall (1960) was 18.3 days and this killed the host trout, and attacks of 5 days' duration killed small trout. The smallest fish scarred was 6.2 inches (157 mm) long. A prey over 200 grams weight died only after 40 hours of parasite feeding under experimental conditions. Hall estimated that an 80-gram lamprey killed 130 grams of fish for each gram of lamprey growth and that, at this rate, populations of chestnut lampreys were a significant mortality factor in stream sport fish populations.

Nomenclature

Ichthyomyzon castaneus — Girard 1859: 381 (type locality Galena, Minn.)
Ichthyomyzon argenteus — Nelson 1876: 52
Ichthyomyzon concolor — Halkett 1913: 11
Ichthyomyzon bdellium (Jordan) — Huntsman 1917: 25

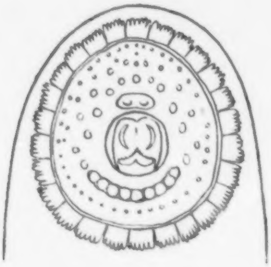
Etymology *Ichthyomyzon* — sucker of fish; *castaneus* — a chestnut, from chestnut colour.

Common names Chestnut lamprey, northern lamprey, western lamprey, silver lamprey, lamprey eel, river lamprey. French common name: *lamproie brune*.

NORTHERN BROOK LAMPREY

Ichthyomyzon fossor Reighard and Cummins

Description A small, nonparasitic, cylindrical lamprey with some lateral compression from the dorsal fins to tail. Usual length to 5.9 inches (150 mm). The short, jawless head, in adults, terminates in a buccal funnel that is always narrower than the width of the body at the gill openings. The buccal fimbrae are vestigial.



All teeth in the buccal funnel are small, blunt, and peglike. The supraoral lamina is a single, bicuspid tooth; the infraoral lamina has 6–11 blunt cusps; there are 4 pairs of single, unicuspid inner lateral (or circumoral) teeth. The rest of the funnel is varyingly filled with radiating rows of unicuspid, anterial, and posterial teeth, no obvious ring of small marginal teeth. Mouth small. On the tongue, the transverse lamina is bilobed, the longitudinal lamina is weakly developed and all lingual teeth are minute. The eyes are small (1.4–1.5% of total length) and high, with a single, median nostril ahead and 7 pairs of gill openings lateral and behind. Fins: first and second dorsals joined, referred to as a single dorsal fin, notched to varying extent but notch never reaching the back; second dorsal higher, connected to broadly oval caudal; anal visible in mature males, more prominent in mature females, otherwise absent, but when apparent, obviously joined to caudal; no paired fins or their supports. No scales, skin smooth, leathery, no prominent lateral line in normal midlateral position, trunk myomeres 51–58. No vertebrae, skeleton cartilagineous (Vladykov 1949a; Hubbs and Trautman 1937). *See* illustration p. 41.

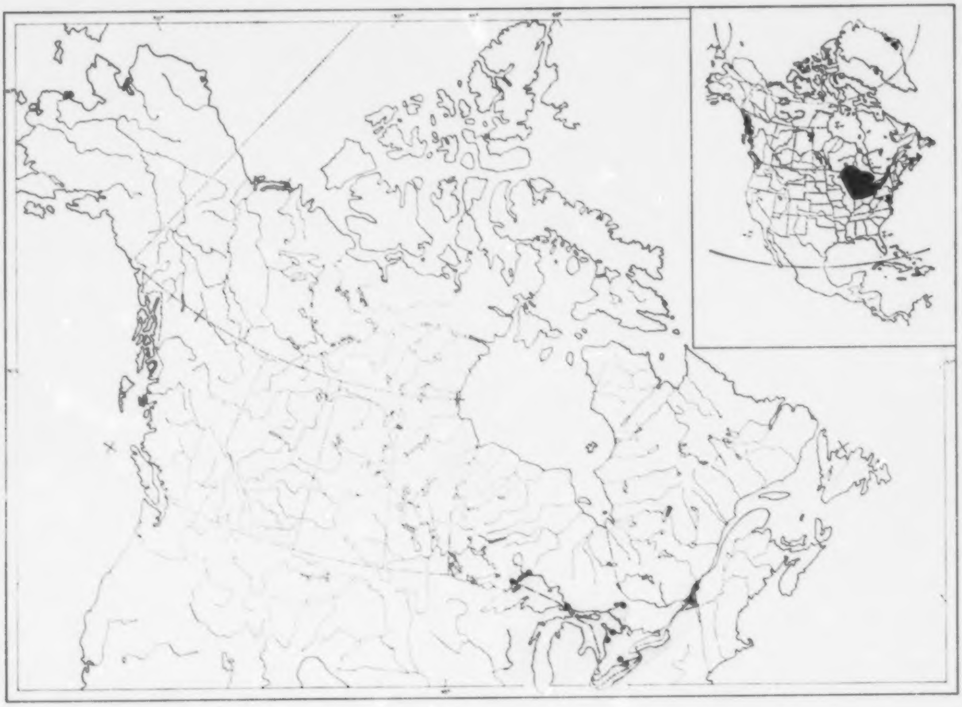
Colour Adults dark grey to brown on back and sides, lower parts grey or silvery white, ventral surface near pharynx often orange or silver, the posterior part of the tail, not caudal fin, dark grey to black, dorsal fin base tan; iris of eye bluish (Vladykov 1949a).

Systematic notes Hubbs and Trautman, in their 1937 revision of the genus *Ichthyomyzon*, considered *I. fossor* to be a degenerative, nonparasitic, brook form, derived from the larger, parasitic form *I. unicuspis*, the silver lamprey. *See Nomenclature* for problems in the synonymy of this species.

Distribution In general, this species occurs in the Mississippi and Great Lakes basins from western New York, Quebec, Ontario, Michigan, and eastern Wisconsin; from the north shore of Lake Superior to northern Indiana and Ohio. Nowhere is it known to be particularly abundant.

Its distribution in Canada extends from the Yamaska and St. Francis rivers of southern Quebec to the Thames River system, Georgian Bay, Lake Nipissing, and the north shore tributaries of Lake Superior.

Biology In Canadian waters, the northern brook lamprey spawns in the month of May or June when water temperatures are 55°–60° F (12.8°–15.6° C) (Vladykov 1949a). There is no conspicuous spawning migration of large numbers of adults (Leach 1940). Spawning takes place in streams and small rivers, on a bottom of coarse gravel, shingle, and stones 1–6 inches (25–152 mm)



in diameter. All spawners are usually in a restricted area, not randomly distributed. The lampreys take up positions in water 8–18 inches (203–457 mm) deep in chinks beneath the larger stones, enlarging the cavities by removing gravel with their suctorial funnel and the sand by vigorous activity of the body. This species makes extensive use of its sucker to move stones during nest preparation. At times a nest 3–4 inches (76–102 mm) in diameter and a maximum of 4 inches (102 mm) deep is excavated in sand or mud but no spawning was ever seen to take place in such a nest. During nest building the body of this species is generally oriented vertically rather than horizontally as in many other species. In the cavity under the rocks, the male attaches to the female, approximates the vent but does not entwine the female, and spawning is accompanied by a vigorous vibration of the two animals (Reighard and Cummins 1916). A few days (Leach 1940) after egg laying is completed, the adults die. Egg size is reported to be about 1.0–1.2 mm in diameter and this species is said to have an average of 1200 eggs (Vladykov 1949a). The eggs, which develop in a gluelike mass, hatch in 2–4 weeks (Leach 1940), and the ammocoetes dig a U-shaped burrow into areas of silt and sand in eddies (Reighard and Cummins 1916).

Length of ammocoete life is, in all lampreys, difficult to determine with assurance, as age must be assumed from length frequency alone. The following age–length relation was recorded for Michigan (Okkelberg 1922; Carlander 1950a):

Age (*years*)	TL(*mm*)	
	Mean	Range
3 months	20	10–30
1	50	35–60
2	65	60–70
3	75	70–80
4	85	80–90
5	95	90–100
6	110	100–120

Allowing for variability, it is assumed that the ammocoete stage of this species lasts from 5 to 7 years depending on location and food. Ammocoetes as large as 6 inches (152 mm) were taken in Indiana (Leach 1940).

Transformation takes place in individuals 4.7–5.9 inches (120–150 mm) in length, but as few as one-third of the ammocoetes of the same year-class transform at the same time. Some transform a year later, remaining in a full-grown, resting period over that time. Time of onset of a 2–3-month period of transformation is from August to mid-September. During transformation sexual development begins, the oral hood becomes a toothed, buccal funnel, the intestine becomes degenerate and functionless, the eyes become much better developed, and length decreases. Much of this takes place while the ammocoete is still in the burrow. The many changes accompanying metamorphosis were well described by Leach in 1940. As transformation proceeds, the animal leaves its burrow more and more. From January on, the nonfeeding adults retreat to burrows only to hide. Transformation is complete by February, and full sexual maturity is attained in May, just before spawning time.

The habitat of this species is creeks and small rivers. It apparently avoids both small brooks and large rivers, and is never taken in lakes or ponds (Leach 1940). The creeks are usually warmer than those suitable for brook trout (Vladykov 1949a).

In this nonparasitic species the adults, and possibly the larger ammocoetes in the resting stage, do not feed. The intestine is nonfunctional. The midsummer food of ammocoetes of most lampreys consists of diatoms, desmids, protozoans, green algae, detritus, and pollen (Creaser and Hann 1929) and they can survive long periods of starvation (Moffett 1966).

Since the ammocoetes are used as bait it would seem logical that larger ammocoetes, once out of the burrow, and adults are probably preyed on by a number of stream fishes. The only record of a predator, however, is the rock bass (Hubbs and Trautman 1937). Lowering of water level is probably a significant ammocoete mortality factor.

Relation to man Since this species is not parasitic it does not have the indirect effect of endangering or destroying fishes. There appear to be no published records of the use by man of this very small lamprey for food. In Quebec, the larger ammocoetes are sold to anglers as bait.

Nomenclature

Ichthyomyzon fossor — Reighard and Cummins 1916: 1 (type locality Michigan)
Ammocoetes unicolor — DeKay 1842: 381
Ammocoetes borealis — Agassiz 1850: 252
Ichthyomyzon (*Reighardina*) *unicolor* DeKay — Creaser and Hubbs 1922: 8
Reighardina unicolor (DeKay) — Jordan, Evermann, and Clark 1930: 9

The synonymy of this species is perplexing. There is considerable confusion involved in uses of the names *unicolor* and *concolor* prior to the revision in 1937 of the genus *Ichthyomyzon* by Hubbs and Trautman. Many of the records were based on unidentifiable ammocoetes and many published records under these names probably refer to more than one species. Records of *unicolor* were often treated by different authors as synonyms of different species. Synonyms given here are those usually attributed to *fossor* but *A. borealis* of Agassiz could just as easily be *I. unicuspis*.

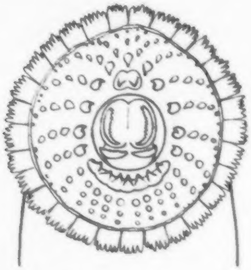
Etymology *Ichthyomyzon* — to suck fish, based on the parasitic feeding habit; *fossor* — a digger.

Common names Northern brook lamprey, Michigan brook lamprey, brook lamprey, blood sucker. French common name: *lamproie du nord*.

SILVER LAMPREY

Ichthyomyzon unicuspis Hubbs and Trautman

Description A moderately large, parasitic, freshwater lamprey, somewhat more laterally compressed than other species. Usual length to 12.9 inches (328 mm). The head is somewhat longer, eyes moderately large (1.8–2.3% of total length); single, median nostril ahead; 7 pairs of gill openings behind; sucking disc definitely greater in diameter than branchial area (9.1–11.4% of total length).



Buccal funnel fringed with fimbriae and well armed with long, curved, sharp teeth; supraoral lamina usually a single, large bicuspid tooth; infraoral lamina rather short with 5–11 short, sharp teeth; inner laterals (or circumorals) 4, unicuspid, not separated nor differentiated, except larger, from other radiating lateral teeth; anterials (or maxillary labials) radiating rows of sharp, unicuspid teeth fill the area, as do the posterials (or mandibular labials) which are smaller; marginal ring inconspicuous. Teeth on tongue small, transverse lamina bilobed with about 35 cusps; longitudinal lamina 2, with 33–40 cusps on each. Fins: dorsals 2, first and second dorsals joined, cleft between them not deep, referred to as a single fin, second dorsal higher, not highly pointed even in mature females; second dorsal connected to rounded caudal; anal not well developed in either sex; no paired fins or supports. No scales, skin smooth, leathery; no lateral line in usual position; trunk myomeres broad and 47–55 in adults, 50–53 in ammocoetes. No vertebrae, skeleton cartilagineous (Vladykov 1949a; Hubbs and Trautman 1937). *See* illustration p. 41.

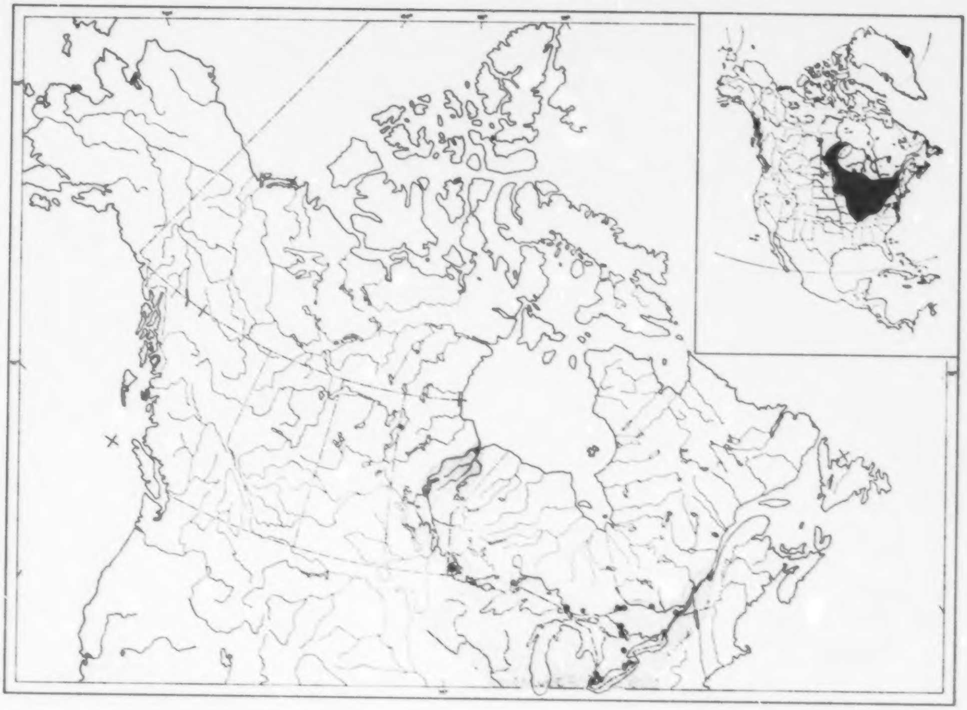
Colour In adults the dorsal surface and upper sides range from brown through silver-grey to blue, shading to lighter blue-grey or silver below. Silver colouration not usually apparent in Quebec. Transformed individuals up to 6.7 inches (170 mm) are without grey or silver pigment and are light yellow to tan below, darker above. Ammocoetes generally paler in colour.

Distribution Restricted to eastern North America, from the St. Lawrence River as far down as Montmagny, Que., west through all the Great Lakes, through the upper Mississippi valley from Wisconsin, to eastern Manitoba; from Manitoba tributaries of Hudson Bay (Nelson River) in the north to the Ohio River basin as far south as Kentucky (Hubbs and Lagler 1964).

Specific localities in Canada other than those mentioned above are Lake Champlain, Lake Ontario (rare), Lake of the Woods, Lake Nipissing (Scott 1967), Nelson and Hayes rivers in Manitoba.

Small's 1883 record of this species, as *Ichthyomyzon Argenteus*, from the Ottawa district, is probably the first record from a truly Canadian locality. Earlier records simply list various Great Lakes.

Biology This species spawns in the St. Francis River, a tributary of the St. Lawrence near Pierreville, Que., in May and June. Adults ascend larger rivers where they construct shallow nests in gravelly riffles by transporting stones in the mouth and by sweeping away sand and silt by vigorously lashing the tail. The male attaches to the head of the female, coils around her so as to



approximate the anus; eggs and sperm are released simultaneously during a rapid vibration of the bodies of the mating pair. After spawning all adult silver lampreys die. Egg size is approximately 1 mm diameter. Egg number averages 10,800 (Vladykov 1949a). The eggs hatch in a few weeks and the ammocoetes burrow into the mud and silt of the margins of the river. Here they live 4–7 years. Metamorphosis probably begins in ammocoetes about 3 inches (76 mm) long, in late fall. Transformation is completed in the early spring, as recently transformed individuals found in May were 3.5–4.3 inches (89–110 mm) in length and weighed 1–2 grams. In this parasitic species, increase in eye size and development of the sharp teeth and a functional intestine, take place during transformation. After transformation the lampreys migrate downstream to a lake. Life span of the adult is probably 12–20 months depending on growth and maturation of eggs. During this period they parasitize lake fishes. Growth of transformed, parasitic individuals from May to November has been given as an increase from 4.3 to 10.0 inches (107–255 mm) and 2.5 to 42.0 grams.

This species may feed over the winter of its parasitic year as well, since maximum size at spawning in Canada appears to be 12.5 inches (318 mm) for females and 11.3 inches (288 mm) for males (Vladykov and Roy 1948) and 12.9 inches (328 mm) in the United States (Hubbs and Trautman 1937). It is stated, however, that length and weight decrease and the intestine becomes progressively less functional as the eggs develop during the winter before spawning occurs.

The silver lamprey inhabits larger rivers and lakes, migrating farther upstream than the chestnut lamprey, *I. castaneus*, in areas where the two occur together. They do not utilize the smaller streams inhabited by the brook lampreys. All species of the genus *Ichthyomyzon* are intolerant of salt water.

Their low abundance in Lake Ontario and greater abundance in the upper Great Lakes may be the result of the long presence of the sea lamprey, *Petromyzon marinus*, in Lake Ontario and the inability of the silver lamprey to succeed in its presence. The non-parasitic northern brook lamprey, *I. fossor*, is believed to be a degenerate derivative of the silver lamprey.

The burrowing ammocoetes are filter feeders who feed on microscopic plants and animals such as algae, pollen, diatoms, and protozoans. The parasitic adults probably feed on a wide range of lake fishes. Scars of this species were noted on 11 species of fishes in Quebec (Vladykov and Roy 1948) including the lake sturgeon, Atlantic sturgeon, and the longnose gar (Bensley 1915). Other species they have been reported to attack are: paddlefish, lake trout, rainbow trout, lake whitefish, northern pike, white sucker, black buffalo, brown bullhead, rock bass, and walleye (Hubbs and Trautman 1937).

The ammocoetes and smaller adults are doubtless preyed on by a variety of stream fishes as they are used as bait for sport fish. Where the silver lamprey and the chestnut lamprey occur together in the United States, they probably compete both for spawning grounds and for food. Stream size, temperature selection, and the apparent absence of *I. castaneus* from lakes, may negate this.

Relation to man This species has obviously been used as food, as the literature refers to material caught in Lake Erie seen in various fish markets (Hubbs and Trautman 1937).

The indirect relation as a result of its predation on economically important commercial and sport fishes is not so significant as that of the sea lamprey. The silver lamprey is smaller, the wound usually shallower and smaller, and it is doubtful that a single lamprey would bring about the death of any large, heavily scaled fish that it might attack. On naked species such as burbot and catfish they often penetrate the body wall and kill the individual.

The ammocoetes may be sold as bait for sport fish.

Nomenclature

Ichthyomyzon unicuspis — Hubbs and Trautman 1937: 53 (type locality Toledo, Ohio)
Petromyzon argenteus — Kirtland 1841b: 343
Ammocoetes concolor — Kirtland 1841b: 473
Ammocoetes borealis — Agassiz 1850: 252
Petromyzon — Fortin 1864: 71
Petromyzon hirudo — Jordan and Copeland 1876: 161
Ichthyomyzon castaneus — Provancher 1876: 262
Ammocoetes hirudo — Jordan 1878a: 120
Ammocoetes argenteus — Jordan 1878a: 120
Lampetra fluriatitis — Ward 1878: 222
Petromyzon nigricans — Ward 1878: 222
Ichthyomyzon Argenteus — Small 1883: 47
Petromyzon concolor — Jordan and Fordice 1886: 282
Ichthyomyzon concolor — Cox 1897: 9
Ichthyomyzon bdellium — Huntsman 1917: 24

Most authors prior to 1937 were using Kirtland's name *concolor*, which was based on unidentifiable ammocoetes. Other names in use up to 1933, as recorded here, are names actually attributable to other forms of North American lampreys, but used by various authors in records that Hubbs and Trautman in 1937 considered, for various reasons, were of the silver lamprey.

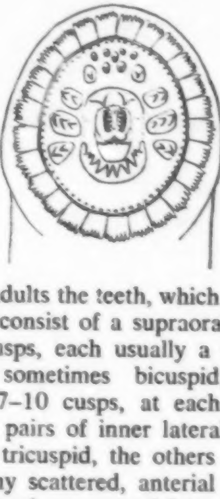
Etymology *Ichthyomyzon* — sucker of fish; *unicuspis* — characteristic single cusps of the inner lateral or circumoral teeth.

Common names Silver lamprey, northern lamprey, brook lamprey, lamprey eel, lamper eel. French common name: *lamproie argentée*.

RIVER LAMPREY

Lampetra ayresi (Günther)

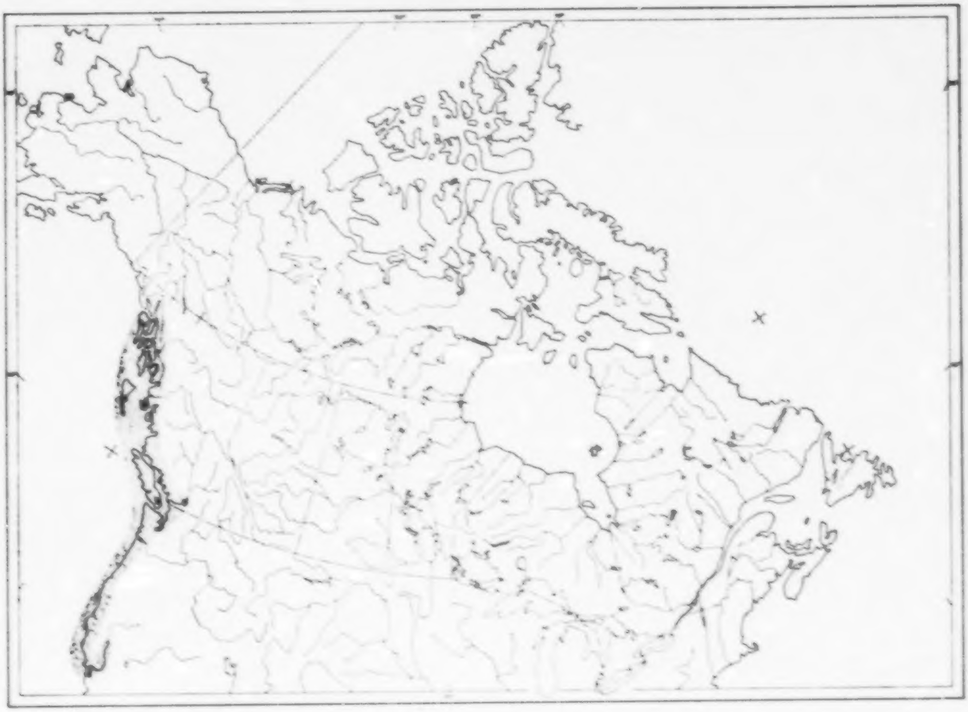
Description The parasitic river lamprey is elongate, nearly cylindrical to the dorsal fins where it becomes laterally compressed. Usual length to 12.2 inches (311 mm). In transformed individuals the short, jawless head has a turned-down buccal funnel edged with leathery fimbriae.



In feeding adults the teeth, which are hooked and sharp, consist of a supraoral lamina of 2 lateral cusps, each usually a single cusp but both sometimes bicuspid; infraoral lamina of 7–10 cusps, at each end often bicuspid; 3 pairs of inner lateral teeth, the centre pair tricuspid, the others usually bicuspid; many scattered, anterial (or maxillary labial) teeth, no posterial (or mandibular labial) teeth; a ring of small, marginal teeth present. On the tongue there are 12–17 transverse cusps, the median cusp much enlarged; and 19–22 longitudinal cusps. Beyond the mouth there are 5 or 6 velar tentacles. The eyes are moderately large and central in adults, with a single, median nostril ahead and 7 pairs of lateral gill openings behind. Fins: dorsals 2, separate but touching, second dorsal higher than first dorsal with pointed apex forward, second dorsal somewhat pointed to flat; pointed caudal forming an acute angle at apex, conspicuously joined to second dorsal and to anal; anal a mere ribbon in males but obvious in spawning females. No paired fins or their skeletal supports. No scales, skin smooth and leathery; no lateral line in usual position, trunk myomeres 60–71 in adults and 65–71 in ammocoetes. No vertebrae, skeleton cartilagineous (Vladykov and Follett 1958). *See* illustration p. 41.

Colour Body dark brown to lead-grey on top and upper sides, silvery around head, gill openings, and lower sides, white on the undersurface. In ammocoetes most of the head is unpigmented, the bulb and ridge of the precursor of the tongue white and without pigment. In both ammocoetes and adults there is a prominent, symmetrical, dark spot on the posterior three-quarters of the tail, hence the French common name, which translated means "blacktailed lamprey" (Vladykov and Follett 1958).

Systematic notes This species, like *L. richardsoni*, was for a long time confused



with a superficially similar European brook lamprey, *L. fluviatilis* (Linnaeus). It was originally described as *Petromyzon plumbeus* by Ayres, but Günther realized *plumbeus* had already been used for a European lamprey, and substituted *ayresii*. This name was later relegated to the synonymy of another European lamprey, *L. fluviatilis*, until re-examination by Vladykov and Follett in 1958 showed that the river lamprey was a distinct form restricted to the Pacific coast of North America and Günther's name for it was revived.

Distribution Restricted to the Pacific coast of North America, from the Sacramento River, Calif., to Tee Harbour near Juneau, Alaska. In fresh and salt water. Probably uncommon in British Columbia although more abundant to the south.

The first record of this species in Canadian waters was a specimen taken in 1942 off Discovery Island, B.C. (Clemens and Wilby 1961).

Biology Very little is known of the life history of this lamprey, and what follows is mainly from Vladykov and Follett (1958). They are parasitic and anadromous. They ascend southern rivers considerable distances (Sacramento River as high as Mill Creek, Tahama County) to spawn. They probably spawn in gravel, with an activity similar to that given for the arctic lamprey, from the end of April through May in California. Egg number in two specimens, 6.9 and 9.0 inches (175 and 230 mm) weighing 20.2 and 24.0 grams, was estimated at 37,288 and 11,398. The eggs were 0.7 and 0.6 mm in diameter. Ammocoetes doubtless burrow into the mud where they live for an unknown period. Transformation is known to have taken place in specimens as small as 4.6 inches and 4.8 inches (117 and 122 mm). A specimen 6.4

inches (162 mm) was found on a fish, indicating that parasitism takes place at least by that size. Transformed lampreys migrate to the sea, are predatory for an unknown period of time and then return to fresh water to spawn. Maximum size is not known but adult females to 12.2 inches (311 mm) and males to 11.1 inches (281 mm) have been taken.

The ammocoetes, as in other lampreys, doubtless feed on microscopic plants and animals. Adults probably prey on a wide variety of fishes. They have been reported as attacking coho salmon (Withler 1955) as small as 3.6 inches (92 mm) in length, and kokanee. The river lamprey is probably preyed on by a number of fishes and birds. The only literature record seen for predators is one that stated that a river lamprey was found in the gullet of a lingcod.

The river lamprey was long referred to as *L. fluviatilis* and thought to be the same as those of rivers of western Europe. Vladykov and Follett (1958) demonstrated the differences between these two and the need to revert to the name *L. ayresi* for western North America.

No definite records of the parasites of this species are available. Those listed for *L. fluviatilis* in 1968 by Ronald and Wilson are doubtless for the European form and not this species.

Relation to man As with most other lampreys, the relation of this species to man is indirect. These lampreys are small, probably never exceeding 13 inches (330 mm). Reports of parasitism are sparse and it seems likely parasitism is of little consequence to economically important fishes. No records of their capture for food are known.

Nomenclature

Petromyzon ayresii — Günther 1870: 505 (type locality British Columbia)
Petromyzon plumbeus — Ayres 1855: 28
Lampetra cibaria (Girard) — Jordan and Evermann 1896–1900: 13
Lampetra ayresii (Günther) — Jordan, Evermann, and Clark 1930: 10
Lampetra fluviatilis (Linné) — Berg 1931: 112
Lampetra ayresi (Günther) — Carl, Clemens, and Lindsey 1967: 29

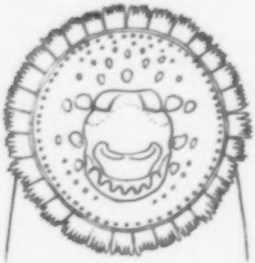
Etymology *Lampetra* — a sucker of stone; *ayresi* — after W. O. Ayres who first described the species from California.

Common names River lamprey, western lamprey, western brook lamprey, parasitic river lamprey. French common name: *lamproie à queue noir*.

ARCTIC LAMPREY

Lampetra japonica (Martens)

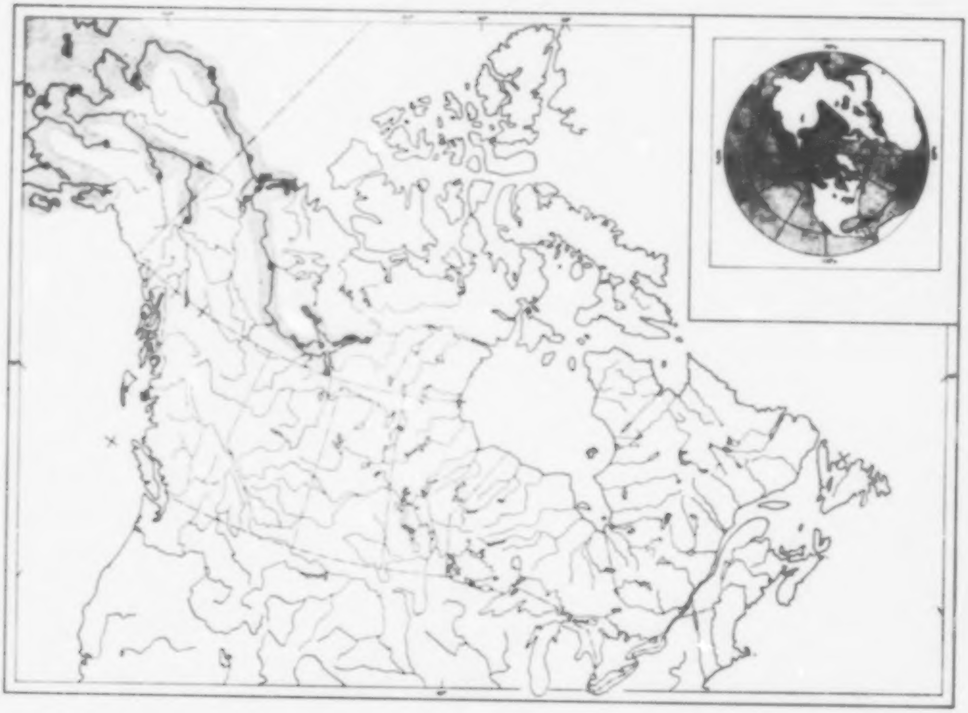
Description The body of the Arctic lamprey is long and cylindrical, somewhat laterally compressed beyond the dorsal fins. Usual length to 11 inches (280 mm). Head short, surrounded by a circular sucking disc edged with leathery fimbriae, eyes small, 7 pairs of gill openings, a single, median nostril.



The teeth in this species consist of a supraoral lamina of 2 (rarely 3) single cusps; infraoral lamina of 5–10 cusps; 2 or 3 pairs of inner lateral (or circumoral) teeth, usually bicuspid; a series of simple posterial (or mandibular labial) teeth; several series of simple anterial (or maxillary labial) teeth. Tongue with several, pointed cusps. In the parasitic form these teeth are strong and sharp, in the nonparasitic populations they are smaller and blunt. At the junction of the oesophagus and respiratory tube there are 5 or 6 velar tentacles (McPhail and Lindsey 1970). Fins: dorsals 2, prominent, higher in males, almost continuous in adults and continuous with the caudal. First dorsal lower, rounded to pointed, second dorsal higher more pointed; anal often a mere fold, can be prominent in mature females. There are no paired fins or girdles. There are no scales; no lateral line in the usual position. Skin smooth, leathery, and marked by 65–80 grooves between the last gill opening and anus in adults and 60–74 in ammocoetes (Buchwald 1968). Skeleton entirely cartilagineous, no vertebrae.

Colour In fresh water, adults are dark brown to blue-black, light brown or grey below. Fins are generally brown and translucent. Ammocoetes are brown to grey, paler below, but have a distinctive pigment pattern by which they can be distinguished from those of other lampreys. In the sea, or newly migratory, adults are steel-blue above, pale to silvery below.

Systematic notes There are both anadromous and dwarf freshwater forms of this species, at least in Alaska. There is a controversy as to whether the smaller, nonmigratory form is parasitic. These factors have led to confusion in the systematics and nomenclature of the Arctic lamprey, such that the Arctic lamprey was long considered synonymous with the small, nonparasitic, American brook lamprey, *Lampetra lamottei*, of eastern North America. The anadromous parasitic form of the Arctic lamprey has been referred to as *L. lamottei japonica* and the nonanadromous, nonparasitic form as *L. l. lamottei* (Wilimovsky 1954). Heard (1966) suggested that both forms are parasitic and should be referred to as *L. japonica*. McPhail and Lindsey (1970) stated that the areas of distribution of the Arctic lamprey and the American brook lamprey are separated by 1500 miles but that ranges and mean number of velar tentacles and of teeth on the infraoral bar are virtually identical. They gave range and mean myomere counts as 64–76 (67.4) in *L. lamottei* from Ontario and Michigan, 68–74 (71.7) in *L. japonica* from the Mackenzie River and 65–80 (69.4) from Alaska. In fact there appears to be no



suitable external characters by which the two can be adequately separated in a key. McPhail and Lindsey suggested that further study may indicate that the eastern and western forms do not warrant specific separation but, pending such study, the two names should be retained.

Distribution This lamprey is said by various authors to occur, as different subspecies, in rivers flowing into the arctic from Norway (Tambs-Lyche 1963) or the White Sea (Walters 1955) to the Ob basin (*L. japonicus septentrionalis* Berg), rivers of Siberia (*L. j. kessleri* (Anikin)), in the Amur River, the Kamchatka Peninsula, rivers of the Sea of Japan, and as far south as Pusan, Korea (*L. j. japonica*).

In North America it occurs in the Anderson River near the coast, in Artillery Lake (northeast of Great Slave Lake into which it drains by a circuitous route) (Buchwald 1968), in Slave River (upstream to Fort Smith), Great Slave Lake, the Mackenzie River, Yukon River (to Dawson, Yukon Territories), and in Alaska from the Kenai Peninsula north.

Biology The life history of this lamprey is clouded by the presence, often in the same habitat, of a larger, parasitic, migratory population and a dwarf, freshwater population considered by some as parasitic (Heard 1966) and by others nonparasitic (McPhail and Lindsey 1970). The Arctic lamprey in North America has been treated by some authors as synonymous with the nonparasitic American brook lamprey, *Lampetra lamottei*, of eastern North America (Wilimovsky 1954; McPhail 1960). The presence of populations of nonparasitic lamprey in Alaska very similar to *L. lamottei* led to this conclusion. Heard's 1966 discussion of the life history of lampreys of the Naknek River, Alaska, led him to conclude that all the lampreys in that system were parasitic and *L. japonica* as distinct from *L. lamottei*. McPhail and Lindsey (1970) said that although the eastern and arctic forms are almost identical, they should be considered separate, pending further work. Most of the available data on this species were given by Heard (1966) and Buchwald (1968) and were the bases for much of the following.

Arctic lampreys spawn from late May to early July in areas out of the main current in streams with moderate flow. Water temperature at spawning time was recorded to vary from 54°–59° F (12.2°–15.0° C). The nests, built in areas of gravel 0.5–2.0 inches (13–51 mm) in diameter, are 6–10 inches (152–254 mm) in diameter and vary from a mere depression in the gravel to a pit 3 inches (76 mm) deep. Both sexes work at nest building by thrashing the anchored body and by carrying individual stones. From 2 to 8 spawners are active on a single site. The sex ratio on the spawning grounds is 1:1 but one female may spawn with more than one male. By means of his sucker, the male attaches to the head of the female and wraps completely around her, the pair vibrate rapidly, and eggs and sperm are emitted simultaneously. Egg number varies from 9790 to 29,780 in various size females in the Slave River. Eggs hatch within a few weeks and the ammocoetes burrow into the soft stream margins. Growth of ammocoetes is variable and confusing, possibly since there are, among any catch, ammocoetes of the anadromous form with greater potential maximum size, and ammocoetes of the dwarf freshwater form. This variability may explain why Buchwald, on the basis of length frequencies of ammocoetes, suggested a 4-year ammocoete period with the following age–length relation:

Year	TL	
	(inches)	*(mm)*
1	0.13	0–35
2	1.2–2.5	30–65
3	2.3–6.1	60–155
4	5.9–8.6	150–220

Heard suggested that immature adults taken in limnetic samples may have represented transformed lampreys-of-the-year. He also said, however, that length frequencies of ammocoetes migrating downstream in spring indicated that more than one age-group was represented. Transformation of both forms apparently takes place in the fall at 6.0–8.25 inches (150–210 mm). Transformed lampreys move downstream from August to November, the anadromous ones to the sea and the freshwater ones to a lake. After an indefinite period in the larger bodies of water where they are parasitic, the adults migrate upstream in the spring to spawn. For at least the freshwater form, it was postulated that adult life lasted only from transformation in August to spawning in the following spring, and that feeding ceased in the winter and the intestine degenerated.

The migrating adults are often seen in vast swarms, particularly at places where their upstream passage is obstructed. Buchwald reported that transformed lampreys found in the Hay River in September might not enter Great Slave Lake until late fall.

Anadromous Arctic lampreys may grow to 24.6 inches (625 mm) and weigh up to ½ pound in the USSR (Berg 1948), but in North America maximum size would appear to be 16.2 inches (411 mm). The freshwater form apparently rarely exceeds 7 inches (180 mm). The length–weight relation for this species (in mm and g) in the USSR (Berg 1948) was as follows:

Total length (*mm*)	380	490	520	540
Weight (*g*)	90	110	145	146

As in other species, the sedentary burrowing ammocoetes feed on microscopic plants and animals. If, as suggested, all adults regardless of size are parasitic, then their food will consist of the body fluids, probably of fishes alone. In Alaskan fresh water this lamprey is known to parasitize sockeye salmon, rainbow trout, pygmy whitefish, and threespine stickleback. A pygmy whitefish of 2.6 inches (65 mm), carried a *L. japonica* of 5.4 inches (137 mm) and a stickleback of only 2.4 inches (60 mm) had been attacked by an Arctic lamprey of 5.8 inches (148 mm). Wounds attributable to this lamprey were reported on lake trout and lake whitefish in Great Slave Lake (Rawson 1951). This lamprey is also known to have attacked chinook salmon, a smelt (Osmeridae), starry flounder (McPhail and Lindsey 1970), ciscoes (*Coregonus* spp.), longnose sucker, and burbot.

Arctic lamprey have been reported as preyed on by several species of fishes including inconnu, northern pike, burbot, and walleye. In Buchwald's Great Slave Lake study, 0.5% of the individuals of five species of predatory fish had *L. japonica* as part of the stomach contents. They are also eaten by various species of gulls, particularly when in migratory concentrations in shallow streams. Sculpins (Cottidae) and other fishes probably prey on the eggs of this species. A probable significant ammocoete mortality factor is lowering stream levels in late spring or summer which strand burrowed ammocoetes in dry stream edges. Adult Arctic lampreys in the sea may compete for hosts with the Pacific lamprey in the area off the Kenai Peninsula.

Parasites listed for *L. japonica* are as follows: Cestoda — *Eubothrium crassum*, *Nybelinia* sp., *Pseudophyllidea* sp., *Scolex pleuronectis*; Trematoda — *Brachyphallus crenatus* and *Lecithaster gibbosus*; Nematoda — *Anisakis* sp., *Contracaecum aduncum*, *Terranova decipiens*; Acanthocephala — *Corynosoma semerme* (Ronald and Wilson 1968), *Triaenophorus crassus* (Buchwald and Nursall 1969).

Relation to man It has been reported (Evermann and Goldsborough 1907b) that native peoples took this species in large numbers in spring through the ice with salmon dipnets. They caught them mainly for dog food, and apparently ate them themselves only when other food was scarce.

As with other parasitic lampreys their greater relation is indirect, in their parasitic habit. Apparently freshwater parasitism on the various life stages of the various species of Pacific salmon is negligible. This is not necessarily so for the marine-dwelling adult. Some attacks causing probable mortality to pink and chum salmon in weirs off the Amur River, USSR, have been recorded (Birman 1950). This species is smaller and therefore probably causes less damage than the Pacific lamprey.

It preys on economically important species other than salmon, such as lake trout and lake whitefish, but probably with little detrimental effect.

It has reportedly been used as bait for sturgeon in the USSR.

Nomenclature

Petromyzon japonicus	— Martens 1868: 3 (type locality Japan)
Petromyzon fluvialis (Linn.)	— Richardson 1823: 705
Petromyzon borealis	— Girard 1859: 377 (type locality Great Slave Lake)
Ammocoetes aureus	— Bean 1882: 159
Lampetra aurea (Bean)	— Jordan and Evermann 1896–1900: 13
Entosphenus japonicus Martens	— Creaser and Hubbs 1922: 11
Lampetra borealis (Girard)	— Jordan, Evermann, and Clark 1930: 10
Entosphenus japonicus septentrionalis	— Dymond 1947: 4
Lampetra (Entosphenus) japonica	— Wynne-Edwards 1952: 5
Entosphenus lamottei lamottei (LeSueur)	— Wilimovsky 1954: 281
Entosphenus lamottei japonicus (Martens)	— Wilimovsky 1954: 281
Lethenteron (japonica)	— Vladykov and Follett 1967: 1074
Entosphenus lamottenii (LeSueur)	— McPhail and Lindsey 1970: 53

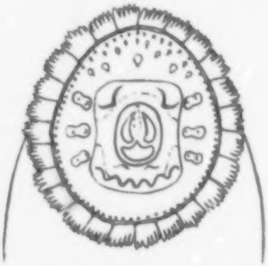
Etymology *Lampetra* — a sucker of stone; *japonica* — of Japan, described by Martens from Japan.

Common names Arctic lamprey, northern lamprey, lamprey eel, Pacific river lamprey. French common name: *lamproie arctique*.

AMERICAN BROOK LAMPREY

Lampetra lamottei (Lesueur)

Description This lamprey is long, cylindrical, and laterally compressed beyond dorsal fins. Usual length to 7.3 inches (187 mm). In adults the short, jawless head ends in a moderately small sucking disc, the diameter, less than that of the branchial region, is 3.6–4.8% of total length. The disc is fringed with leathery fimbriae.

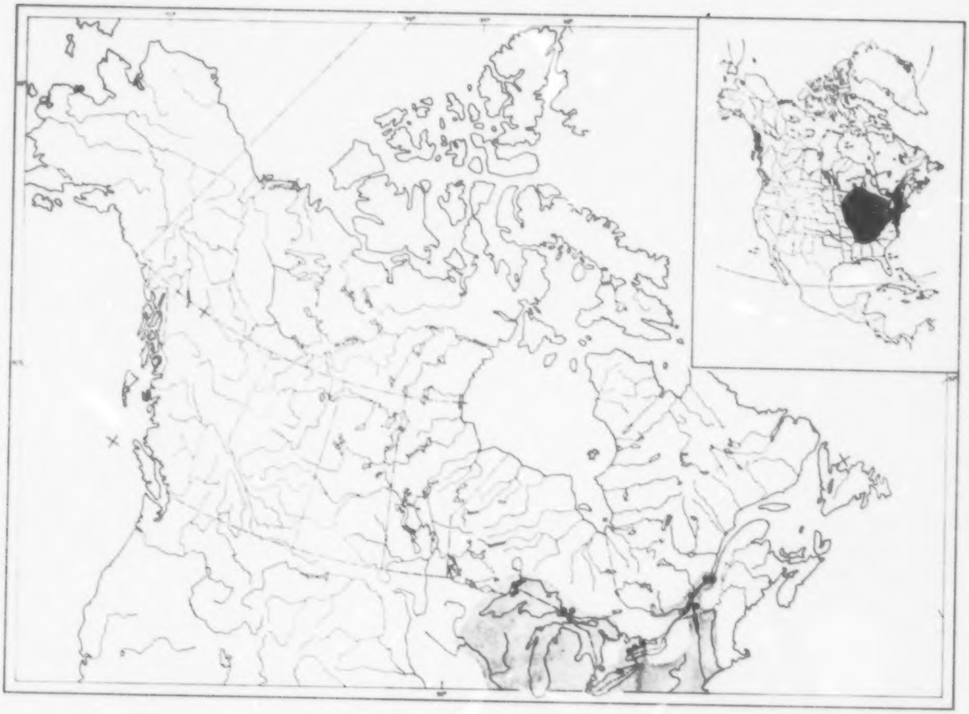


The inner surface of the disc or funnel weakly toothed, teeth not in radiating series; supraoral lamina broad with 2 large, blunt cusps, rarely a third centre cusp; infraoral lamina broad with 6–10, wide, low, blunt cusps; 3 pairs of weak, blunt, bicuspid, inner lateral (or circumoral) teeth, no lateral teeth beyond these; many scattered, somewhat sharper, anterial (or maxillary labial) teeth; a single, curved row of inner posterial (or mandibular labial) teeth connecting the lower, inner lateral pair; marginal ring present but teeth tiny; tongue toothed, transverse lingual lamina not bilobed, with a denticulate ridge and 15 rather large cusps; longitudinal lamina with 5–8 small cusps. The eyes are high and moderate in size in adults, diameter 1.9–2.2% of total length, poorly developed in ammocoetes; a single, mid-dorsal nostril ahead and 7 pairs of round gill openings behind. Fins: dorsals 2, first dorsal and second dorsal narrowly separated, cleft reaches dorsal surface of body (except in spawning males), but referred to as 2 dorsal fins, first dorsal shorter, rounded, often with square edge at insertion, second dorsal higher, rounded in males, pointed in females, connected to spade-shaped caudal; caudal in mature females connected to obvious anal, not apparent in males; no paired fins or their skeletal supports. No scales or denticles; skin, smooth and leathery; no lateral line in usual position; trunk myomeres, 64–70 in adults and 63–70 in ammocoetes. No vertebrae, skeleton cartilagineous, notochord persists. *See* illustration p. 41.

Colour Dorsal surface of body blue-grey in spawners, through slate-grey to muddy brown, shading down sides, much paler on ventral surface; fins with a dirty yellow tinge; dark blotch on base of caudal fin around the notochord. Ammocoetes a pale brown colour. Gage in 1928 described a vivid, red spot on the leading edge of second dorsal which he said was an oedema suffused with blood.

Systematic notes Alaskan populations of lampreys with many superficially similar characteristics were once considered to be this species. A parasitic form was referred to as *L. lamottei japonica*, and another form, thought to be nonparasitic, as *L. l. lamottei* (Wilimovsky 1954). The recent tendency is to look upon both the forms in Alaska and northern Canada as *Lampetra japonica* and as distinct from *L. lamottei* of eastern North America, and to regard *L. lamottei* as a nonparasitic derivative of *L. japonica*. There would appear to be no external characteristics which would adequately separate the two species in a key.

In an important work on lampreys edited by Hardisty and Potter (*see Suggested Reading*), Hubbs and Potter used the name *L. lamottenii* stating that *L. lamottei* is an amendation not presently authorized.



Distribution Restricted to east-central North America, on the eastern seaboard from the Connecticut River south to Maryland; in the St. Lawrence River and tributaries from Montmagny southwest throughout the Great Lakes basin, west to southeastern Minnesota. South of the Great Lakes it occurs in the Mississippi River drainage from New York to Minnesota in the north, south to Tennessee and Missouri.

In Canada it occurs in streams flowing into the St. Lawrence River, Lake Champlain, in the Great Lakes, other than the eastern portion of Lake Ontario, and in the Noire, Ste. Anne de la Pérade, and St. Maurice rivers of Quebec.

Biology This species spawns in spring, usually from early May to early June in Canada, in cold brooks and small rivers. The peak of spawning activity is usually at a water temperature of 62° F (16.7° C) (Vladykov 1949a). Nests, constructed in gravel by the adults (males arrive and begin first), are small gravel-filled pockets less than 1 foot (305 mm) in diameter, between large, round stones. Groups of lampreys up to 3 or 4 dozen may spawn in an area of a few square metres with 3–25 in a single nest (Young and Cole 1900). Males outnumber females 5:1. There is extensive carrying of gravel in the mouths, but this activity often appears random and aimless as if part of a ritual rather than real nest clearing. The spawning act is at irregular intervals and each lasts only 3 seconds. The female attaches to a stone, the male attaches to the head of the female, coils half around her in one left-hand turn, the vents approximate, the tails are turned down and eggs and sperm emitted during vigorous vibration, which stirs up sand (Dean and Sumner 1897). The eggs, which are sticky, adhere to the sand and fall to the nest rather than being carried downstream. Nest activity between spawning acts covers the eggs. After spawning the adults die. Estimates of egg number vary from a low of 860 (Dean and Sumner 1897) to 3276 for a female of 8.5 gram weight (Gage 1928), depending on size. Eggs are about 1 mm in diameter. They hatch in a few days to a few weeks, depending on water temperature. The ammocoetes are thought to live in the sand of the nest until the yolk is absorbed, then they burrow into the sand and silt. The nonparasitic American brook lamprey has a 5- or 6-year life span.

There is a sixfold increase in size over the first season and the range of ammocoete total length (mm) at each age has been calculated by Hubbs (1925a) as follows: age 1(20–40); age 2(40–75); age 3(75–100); age 4(120–140); age 5(140–180).

Growth rate decreases over this range with a second increase immediately before metamorphosis and a decrease in actual size accompanying transformation and sexual maturity. Transformation usually takes place, in the burrow, in the fall and winter of the fifth year at lengths of 4.4–7.4 inches (112–187 mm) (Vladykov 1949a). Not all ammocoetes of one year-class metamorphose in the same year, some may starve, grow little more, but live to transform the following year. Adults were observed to range in length from 7.3 to 7.9 inches (185–200 mm). Transformation and sexual maturity are completed only shortly before the spring spawning season and the adults are not capable of feeding, the intestine having become nonfunctional. This species is not known to grow larger than 8 inches (203 mm).

The habitat of this brook lamprey is the colder brooks and small rivers where it is usually associated with the slimy sculpin and the brook trout. It spends its whole life in the streams and never migrates to lakes. This species prefers cooler streams than the northern brook lamprey, *Ichthyomyzon fossor*.

Summer food of the burrowing ammocoetes of this species is microscopic plant and animal life, probably diatoms, desmids, protozoans, filamentous green algae, pollen, and detritus (Creaser and Hann 1929). Since this is a nonparasitic species, the adults, who live no more than 5 or 6 months, do not eat at all. The intestine is nonfunctional.

Since this species is utilized as bait for sport fish, it would seem likely that the ammocoetes and possibly the adults are fed on by many fishes, such as speckled trout, which cohabit the cool streams. This species may compete with other species of lampreys for spawning grounds, adequate areas for ammocoetes to burrow, and for food. Variation in stream level could be a significant ammocoete mortality factor.

The only parasites recorded for this species were *Aeromonas liquifaciens* (Schizomycetes) and *Cucullanus* sp. (Nematoda) (Ronald and Wilson 1968).

Relation to man Since it is small, secretive, and exists as an adult only long enough to spawn, it is unlikely this species was ever used as food by humans. Since it is a nonparasitic lamprey it has no indirect relation through destruction or impairment of economically important species of fishes.

In Quebec, the ammocoetes of this species, with others, are sold as bait for such sport fishes as walleye, smallmouth bass, muskellunge, and striped bass. Even in 1947–1948 lamprey ammocoetes were sold for 50¢ to $1 a dozen and close to 100,000 were sold around Quebec City (Vladykov 1949a).

Nomenclature

Petromyzon Lamottenii — LeSueur 1827: 9 (type locality Missouri)
Petromyzon appendix — DeKay 1842: 381
Lampetra wilderi Gage — Jordan and Evermann 1896–1900: 13
Entosphenus appendix DeKay — Hubbs 1926: 7
Lethenteron appendix (DeKay) — Jordan, Evermann, and Clark 1930: 9
Entosphenus lamottenii (LeSueur) — Hubbs and Lagler 1941: 26
Entosphenus lamottei lamottei (LeSueur) — Wilimovsky 1954: 281
Entosphenus lamottei (LeSueur) — Scott 1958: 3

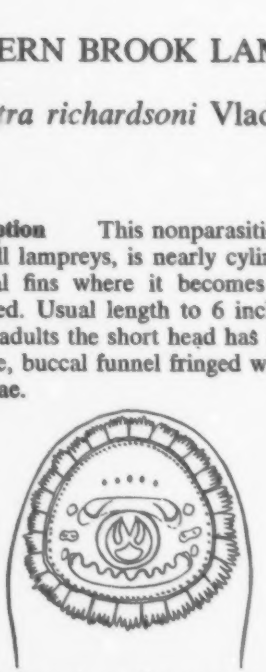
Etymology *Lampetra* — sucker of stone; *lamottei* — after Lamotte, a French explorer, who in 1720 discovered a mine in Jackson Co., Missouri, near where the type specimens were discovered by Lesueur in 1820.

Common names American brook lamprey, brook lamprey, small black brook lamprey, small black lamprey, lamper, lamper eel. French common name: *lamproie de l'est.*

WESTERN BROOK LAMPREY

Lampetra richardsoni Vladykov and Follett

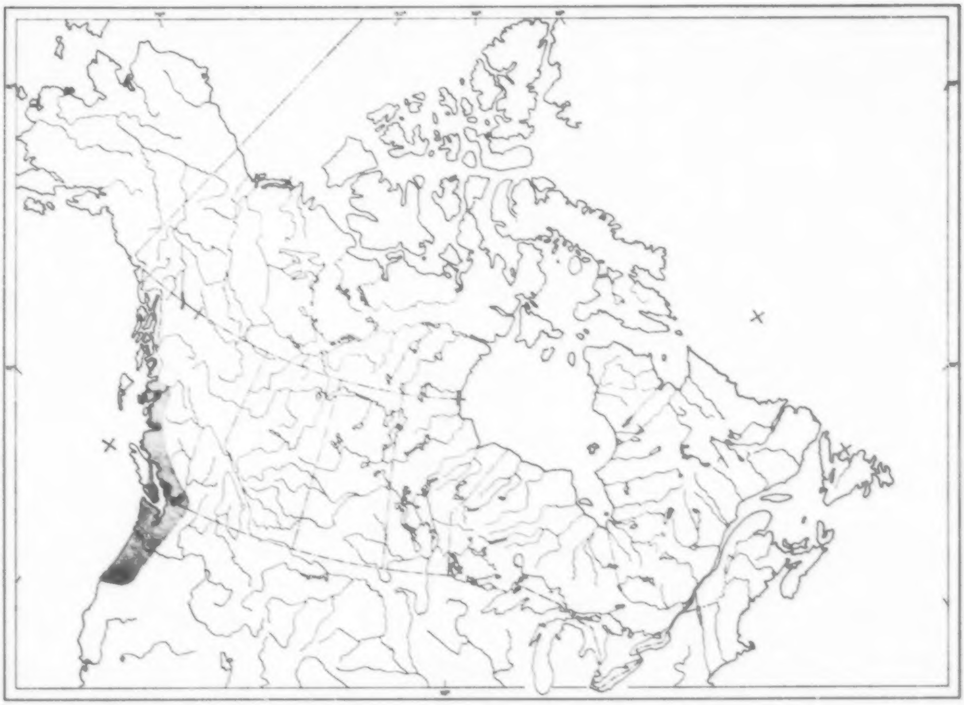
Description This nonparasitic species, as with all lampreys, is nearly cylindrical to the dorsal fins where it becomes laterally compressed. Usual length to 6 inches (154 mm). In adults the short head has a moderately large, buccal funnel fringed with leathery fimbriae.



Within the funnel are the numerous, small, blunt teeth; a broad supraoral lamina of 2 prominent, blunt, single cusps; infraoral lamina of 7–10 rounded, blunt cusps; 3 pairs of small, inner lateral (or circumoral) teeth, the outer ones unicuspid or bicuspid, the centre one usually bicuspid but at times tricuspid, the anterials (or maxillary labials) tiny, peglike, and scattered; no posterials (or mandibular labial); marginal ring present, but tiny and inconspicuous. On the tongue the cusps of the transverse and longitudinal lamina are small and irregular. Beyond the mouth are 5 or 6 velar tentacles. The eyes in adults are moderately large and high; a single, median nostril ahead; 7 pairs of gill openings behind. Fins: dorsals 2, first dorsal lower and flat to pointed, second dorsal touching first dorsal but distinctly separate, second dorsal higher than first dorsal and pointed in females. At spawning time there is a significant swelling of the anterior edge of second dorsal in females but not in males (Pletcher 1963); caudal forms obtuse angle at apex, obviously joined to second dorsal and to anal; anal a mere ribbon in males to an obvious lobe in females; no paired fins or supports. No scales, skin smooth, leathery. No lateral line in usual position, 57–65 myomeres in ammocoetes and 60–67 in adults. No vertebrae, skeleton cartilagineous. Many of the above details were derived from Vladykov and Follett (1965). *See* illustration p. 41.

Colour Adults are brown through olive to black on the upper surfaces, paler below. The fins are a translucent olive-green and the caudal conspicuously marked with diffuse black pigment. The characteristic pigment pattern of ammocoetes was extensively described in Vladykov and Follett's original description of 1965.

Systematic notes The western brook lamprey was long confused with the superficially very similar European brook lamprey



L. planeri (Bloch). It was not recognized as a distinct species, *L. richardsoni*, limited to the Pacific coast of North America until so described by Vladykov and Follett (1965).

Distribution Limited to western North America; in freshwater streams of the Pacific coast (including Vancouver Island and King Island), possibly from Alaska, from British Columbia south to Oregon and possibly California. McPhail and Lindsey (1970) and Carl et al. (1967) listed British Columbia only, but Vladykov and Follett (1965) said they identified ammocoetes from Alaska as *Lampetra richardsoni*. Vladykov and Follett (1965) said to Oregon; Schultz (1930) quoted Hubbs (1925a) on specimens at San Jose, Calif. In British Columbia it is known to occur in the Cowichan River, Vancouver Island; streams entering the Fraser River; and Hooknose Creek, King Island.

Biology Very little was known of the biology of this species prior to the work of Pletcher (1963) and McIntyre (1969). Much of what is given below is from these sources. This nonanadromous lamprey spawns during the day and night in fresh water in the spring and early summer, over a temperature range of 46°–68° F (7.8°–20.0° C). Greatest activity was observed at temperatures of 48°–52° F (8.9°–11.1° C). Time of spawning, depending on local temperatures, is from late April to early July, and is more protracted than for other lampreys. The nests, crude and ill-defined, 2 inches (51 mm) in depth and 4–5 inches (102–127 mm) in diameter, are made, mostly by the males, in coarse gravel ($\frac{1}{16}$ – 4 inches diameter) and sand at the head of a riffle in quiet water (2.3 ft/sec) of smaller rivers and creeks. Aquarium experiments showed that the presence in the tank, for 5 minutes, of ripe females quickly initiated in males nest digging up to 2 hours' duration. Nests are made mainly by vibrating the body and tail; stones are apparently only rarely carried in the mouth, and then only for short distances. McIntyre observed that ¾-inch (19-mm) stones were carried up to 6 inches (152 mm) by both sexes digging the nest, and that stones were pushed in front of the head or carried in the disc when covering eggs after spawning. A single nest may contain as many as 12 spawning lampreys and may be occupied by several different groups of lampreys over the whole spawning period. At spawning, the male carries out a short prespawning "sliding–feeling" courtship during which it slides gently up the body of the female with the disc in light contact with her body, then attaches itself to her head, and coils around her so that the vents approximate. The shedding of eggs and sperm takes place during rapid vibration of the pair. Egg number varies with size of the female. For females 4.4–7.7 inches (111–196 mm) in total length, egg number ranges from 1100 to 3700. Eggs are slightly oval, 1.05–1.13 mm long and 0.98–1.09 mm wide. The spawning act lasts for only a minute. McIntyre noted that 10–12 eggs were released during each spawning act and that spawning acts were separated by periods of egg covering or nest construction. He noted that one pair spawned six times and then abandoned the nest. More eggs must be laid each time or this female had spawned elsewhere previously. Eggs are adhesive and cling to sand swept up in the violent vibration during spawning. The sand carries the eggs down into the nest preventing them from being swept away by the currents. Violent thrashing of the body of the female also probably frees more mature eggs from the ovary in preparation for shedding. The adults live for a very short time after spawning, as dead adults are often found on the banks near the nests.

Eggs probably hatch in 10 days in water 50°–60° F (10.0°–15.6° C) in Oregon (15 days at 60°–68° F or 15.6°–20.0° C in tanks) and the ammocoetes have by 30 days burrowed into the silt at the stream margin. Spawning success and survival is apparently high, as ammocoetes of this species are said to be one of the most abundant forms of life in the lower courses of streams in the northwestern United States, 170 per square metre. This is in spite of the fact, noted by McIntyre, that superimposition of nests of successive pairs occurs, and that the digging of later pairs frees earlier eggs which drift downstream. This may occur only where suitable spawning sites are limited. It is apparently a frequent occurrence in Cultus Lake, B.C. There is little movement of ammocoetes, as individuals 0.3–5.2 inches (8–132 mm) in length were found in the same location, and newly transforming ammocoetes were as abundant upstream as down. Ammocoete life in this species was once thought to span 3–5 years with modal sizes in Washington given by Schultz (1930) as follows:

Age	Length	
(*years*)	(*inches*)	(*mm*)
1	1.6–2.0	40–50
2	2.8–3.2	70–80
3	3.9–4.3	100–110
4	5.5–5.9	140–150

Age–length relation derived by Pletcher from length frequency polygons of ammocoetes from the Salmon River, B.C., indicated an ammocoete life of at least 6 years, as follows:

Age	Mean TL		Range TL	
(*years*)	(*inches*)	(*mm*)	(*inches*)	(*mm*)
0	0.7	17.5	0–0.9	1–22
1	1.4	36.0	1.1–1.8	28–45
2	1.9	47.5	1.6–2.2	40–50
3	2.3	58.0	2.0–2.6	52–65
4	2.8	72.0	2.6–3.2	65–80
5	3.7	95.0	3.0–4.6	76–116

Pletcher also postulated an ammocoete rest period of almost a year, prior to and during transformation.

From August to November the larger ammocoetes metamorphose and adults vary in length from 5 to 8 inches (130–200 mm). The mean size of adults is different in the various rivers, e.g. Salmon River 120 mm, Smith Creek 143.8 mm, and Hooknose Creek 167.2 mm. These overwinter without feeding, start to mature sexually in March, spawn, and die. The largest recorded Canadian specimens were an ammocoete 6.1 inches (156 mm) and an adult 6.4 inches (163 mm) in length.

This species is nonparasitic, the adults do not feed at all, and the intestine is degenerate. They doubtless exist from transformation to spawning on body reserves. Like other lampreys, the burrowing ammocoetes live on microscopic plant and animal matter, including desmids, diatoms, algae, and detritus. Diatoms make up more than 20 times the volume of other items of food consumed.

This brook lamprey may compete in places with *L. ayresi* and *E. tridentatus* for nesting space; however, they probably nest in smaller bodies of water and not so far upstream as the parasitic lampreys. Various sculpins, especially the torrent sculpin, and salmonids prey on the eggs at spawning time. Since they are used as bait, one would assume that this species is preyed on by other fishes. In experimental situations the smallest ammocoetes were readily eaten by coho salmon fry. However, larger ammocoetes were tasted and rejected by as many as 50 cohos in 30 minutes. If skinned, the ammocoetes were readily eaten and the isolated skin rejected. This reaction, similar to that noted in the case of the Pacific lamprey, is thought to be the result of secretion of granular cells in the skin. Since they are used as bait, then the reaction is obviously exhibited by only some species.

The only other animal reported seen eating the spawning adults was a raven, *Corvus corax*.

Ronald and Wilson in 1968 listed parasites of *L. planeri*, but their sources all appear to be European and do not refer to those North American populations long referred to by that name.

Relation to man Since this is a nonparasitic lamprey it does not have the indirect relation of destruction of economically important fishes.

The larger ammocoetes or newly transformed adults were at one time extensively gathered for bait in Washington. They were used by anglers fishing for bass and trout and were said to be better than salmon eggs or sculpins (Cottidae). One bait dealer is said to have sold $3000 worth, at $1.50–$1.75 per dozen, in a single year. There are no recorded sales as bait in British Columbia but sport fishermen dig ammocoetes and collect adults which they use as bait for sturgeon in the Fraser River.

Nomenclature

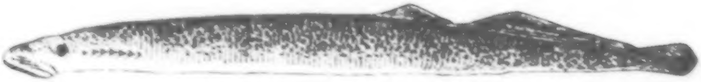
Lampetra richardsoni	— Vladykov and Follett 1965: 139 (type locality Smith Creek, Cultus Lake, B.C. Holotype NMC 64-57)
Petromyzon branchialis	— Günther 1870: 505
Lampetra planeri Bloch	— Creaser and Hubbs 1922: 13

Etymology *Lampetra* — a sucker of stone; *richardsoni* — after Sir John Richardson, British surgeon-naturalist, and author of many important early works on North American fishes.

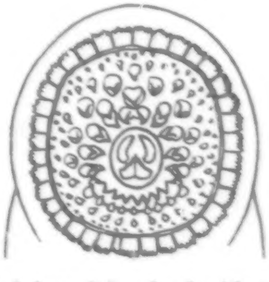
Common names Western brook lamprey, nonparasitic brook lamprey, lamprey eel. French common name: *lamproie de l'ouest*.

SEA LAMPREY

Petromyzon marinus Linnaeus



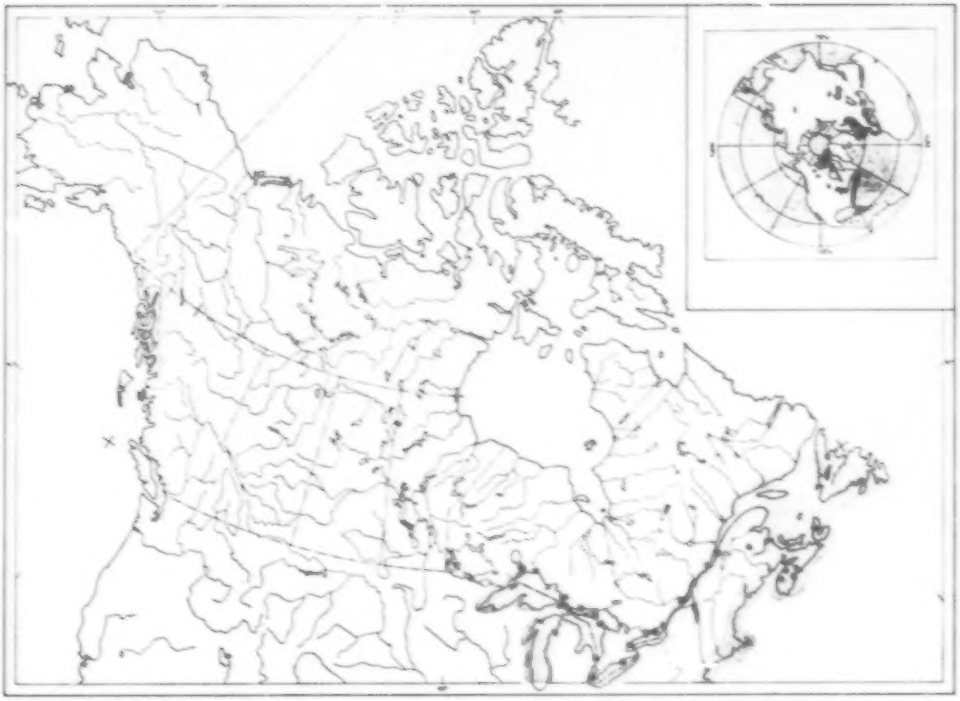
Description This species, the largest and most predaceous of the lampreys, is long, nearly cylindrical to the dorsal fins where it becomes more laterally compressed. Usual length to 33.8 inches (860 mm). The short head terminates in a large sucking disc, diameter as great or greater than diameter of branchial region, 6.1–9.3% of total length varying with body length; eyes large, particularly in newly transformed adults, 2.7–3.6% of total length at 5.1–5.8 inches (131–148 mm); a single mid-dorsal nostril; 7 pairs of conspicuous gill openings laterally.



The buccal funnel is edged with prominent fimbriae and filled with large, hard, hooked, sharp teeth; supraoral lamina a large bicuspid tooth; infraoral lamina of 6–10 large, sharp cusps; 4 pairs of bicuspid inner laterals; anterials and posterials consisting of radiating series of sharp unicuspid teeth, posterials (mandibular labials) somewhat smaller; marginal ring present. The tongue is heavily armed with teeth, the large bilobed transverse lamina has 15 cusps and each of the paired longitudinal laminae has 12–14 large cusps. Fins: dorsals 2, first and second dorsals distinctly separate in ammocoetes and small adults, separate but closer in spawning adults, more widely separated in breeding males of anadromous lampreys than in landlocked ones, considered as two fins; first dorsal lower, flat on top, height 20% of base length, preceded by ropelike ridge in spawning males of landlocked form; second dorsal higher, height more than 20% of base length, base length twice that of first dorsal, pointed. Second dorsal narrowly connected to broadly pointed caudal; caudal in spawning individuals connected to low anal in females; no paired fins or their skeletal supports; no scales, skin smooth and leathery, 67–74 trunk myomeres; no lateral line in usual position; no vertebrae, skeleton cartilagineous, notochord persistent.

Colour Colour differs with sexual development and between the anadromous and landlocked populations. Newly transformed adults 5.3–6.9 inches (135–175 mm) long are grey-blue above, grading gradually to a metallic violet on sides to silver-white on ventral surface.

In adults over 17.7 inches (450 mm), body and first dorsal marbled or blotched with dark brown to black patches. Body of landlocked form is grey-blue in the parasitic phase and golden brown when spawning, a dark blotch at the end of the caudal fin. Increased size (between 14 and 18 inches or 350 and 450 mm) and increased sexual development affected colour changes from blue-black through dark olive, bronze and sienna to xanthine orange in landlocked specimens in Cayuga Lake, N.Y. (Wigley 1959). The supplement to the 1972 annual report of the N.Y. State Conservation Department (1928)



has good colour plates of a spawning male and female of the landlocked form.

The ammocoetes are pale grey to pale brown on top and sides, lighter below. *See* Vladykov (1950) for distinctive pigment pattern and distinguishing characteristics of ammocoetes.

Systematic notes The landlocked populations of smaller lampreys were long considered a distinct species. Jordan and Fordice, as early as 1885, concluded that the "lake lamprey" was not separable from the sea lamprey. It was, however, considered to be subspecifically distinct as late as 1922 (*P. m. unicolor*, *P. m. dorsatus*). It was also at times confused with the other common lamprey in Lake Ontario, the silver lamprey *Ichthyomyzon unicuspis*. Wright in 1892 illustrated a sea lamprey buccal funnel, called it *P. concolor* (a synonym of *unicuspis*), gave it the common name silvery lamprey, and seemed at times to be describing both species.

Distribution The larger anadromous form is common on both sides of the Atlantic Ocean; in the east, from Iceland, the Faeroe Islands, and northern Norway, south to northwestern Africa, including the Baltic, Mediterranean, and Adriatic seas; in the west, from southwestern Greenland and the Grand Banks, the Gulf of St. Lawrence, and as far up the St. Lawrence River and its tributaries as Sorel, Que., south to northeastern Florida (Vladykov 1949a; Bigelow and Schroeder 1948; Scott and Crossman 1964; Leim and Scott 1966). Although common in all other Maritime Provinces, rare in the fresh waters of Newfoundland.

Populations of smaller, landlocked or nonanadromous lampreys were known to occur, prior to 1920, in the upper St. Lawrence River, Lake Champlain, the Finger Lakes, N.Y., and Lake Ontario and its tributaries. The destructive effect of the explosive increase in numbers of this parasite when it gained access to new territory in the upper Great Lakes is now a biological legend, along with the water hyacinth, the prickly pear, and the rabbit in Australia. The opening of the Welland Canal in 1829 first gave this species access to the upper Great Lakes but it was not discovered in Lake Erie until 1921, Lake St. Clair 1934, Lake Michigan 1936, Lake Huron 1937, and Lake Superior 1946. It now occurs throughout the Great Lakes watershed and spawns in all suitable, gravelly rivers to which it has access. The sea lamprey took almost 100 years to invade Lake Erie, but in the following 25 years it spread throughout the system, explosively developing large populations everywhere except in warmer Lake Erie, which also has fewer suitable spawning rivers (Hubbs and Pope 1937; Applegate 1950).

Biology Sea lampreys spawn in the spring. Adults congregate in the estuaries of rivers during late winter, starting to move upstream during the dark hours, at a rate of ½–1 mile/day (Wigley 1959), once stream temperature exceeds 40° F (4.4° C). As many as 25,000 adults may migrate into the same river, moving upstream as much as 49 miles for landlocked lampreys and up to 200 miles for anadromous populations, to areas where the bottom is a mixture of sand, gravel, and rubble, water depth is 15–24 inches (381–610 mm) and there is a moderate current. Migrating adults can manage rapids easily by alternately swimming and attaching to stones. They can surmount nearly vertical barriers of 5 or 6 feet (152–183 cm), over which the current is not excessive, by creeping up the face with the suctorial disc. Early migrants can be on the grounds 6–8 weeks before spawning begins. Nest building is usually begun, in late May or early June, by the males, the females joining them 48–72 hours later. Small stones are carried or dragged out of the chosen site, by means of the sucking disc, and lighter material cleared by the thrashing action of the body. The nest is usually 10.0–39.5 inches (254–1003 mm) in diameter and as much as 25 pounds of gravel, rubble, and sand are moved in such a way that this material forms a downstream, crescentric lip often as high as 10 inches (254 mm). Spawning activity starts when stream temperature reaches 52° or 53° F (11.1°–11.7° C), usually in mid-June, and is at its peak when temperature is 58°–60° F (14.4°–15.6° C), but late migrants can spawn as late as end of July when the temperature is as high as 76° F (24.4° C).

In 77% of 338 nests observed in a Michigan study (Applegate 1950), a single pair spawned in the nest and remained mated for the entire spawning period. Polygamous and polyandrous combinations involving from one to five individuals were also noted, but polygamous and promiscuous pairing seemed to take place only after the peak of spawning activity, when females outnumbered males. Males of single pairs would aggressively drive intruding males off the nest.

During the spawning act the female anchors herself to a stone at the anterior edge of the bottom of the nest, the male carries out an "approaching–sliding" action, moving the disc anteriorly along the body of the female, attaches to the forward dorsal surface of the female and wraps the posterior third of his body in an abrupt, half-spiral about the female in such a way that the vents approximate. Extrusion of eggs and milt is preceded and accompanied by rapid vibration of the two bodies for 2–5 seconds and then the two part. This is repeated after intervals of 1–5 minutes. About 20–40 sticky eggs are released and fertilized during each act, adhere to sand disturbed by the thrashing, and are carried by the current to spaces between the stones in the high posterior lip of the nest where they adhere. In the intervals, male and female move about moving more stones and sweeping more sand onto the lip. Spawning may continue from 16 hours to 3½ days, during the peak of activity spawning is completed in 16–48 hours.

Egg production varies directly with length and weight of female. Calculated mean total egg numbers for females in Michigan between 12.5 and 21.5 inches (318–546 mm) were

34,000–110,300. In the larger anadromous populations, egg number can be as high as 236,000. Ripe eggs were from 0.80 to 1.25 mm (mean = 1.10) in diameter in Michigan lampreys.

Feeding ceases prior to migration and over the period of migration, and most rapidly during the peak of spawning the following changes take place in adults: intestinal tract reduces in size until it is a mere hollow thread; sight deteriorates to complete blindness; colour of liver changes from reddish orange to green; large patches of epidermis and mucal coat slough off and flesh becomes discoloured.

After completion of spawning, females drop downstream from the nest almost immediately and die very quickly. Spent males may cling to the nest in a curled position for 1–3 days before dropping downstream where they die.

Hatchery rearings of eggs showed that Cayuga Lake eggs hatched in 13–14 days at 57°–65° F (13.9°–18.3° C) (Wigley 1959) and 65° F (18.3° C) was the optimum for most rapid and successful artificial hatching (Piavis 1961). It was estimated in Michigan that larval production was a maximum of 1.1% of the reproductive capacity (total eggs laid) of the female, or 662 larvae leaving the nest from a deposition of an estimated 56,600 eggs. Ammocoetes burrow out and leave the nest in 18–21 days at 71° F (21.7° C) after completion of spawning, or 4–8 days after hatching, and are at that time 6.25–9.75 mm total length (mean = 8.54). They very quickly drift downstream to eddies or pools with areas of sandy silt and mud into which they immediately burrow, tail first, about 13 mm deep, often in densities of 6–17 per square foot. Here, in U-shaped burrows, they remain throughout their ammocoete life, coming to the surface to feed.

Ammocoete period, including the period of transformation prior to leaving burrow, was long thought to be a maximum of 4 years but work in the 1960's in the Great Lakes and Cayuga Lake now makes 7 years (age-groups 0–6) a more likely figure with age–length relation (for Cayuga Lake) from Wigley (1959) as follows:

Age group	Modal TL		Approx range TL
	(inches)	*(mm)*	*(mm)*
0	0.47	12	7–16
1	1.46	37	22–50
2	2.36	66	50–75
3	3.23	81	75–95
4	4.21	106	95–118
5	5.00	127	118–137
6	5.59	140	137–162
7	5.39	136	112–167

Transformation takes place in the burrows and starts in mid-July to September of the eighth year (age-group 7) at lengths of 4.4–6.6 inches (112–167 mm) and is externally completed in a period of 1 or 2 weeks. Internal changes may not be completed until March of the following year. The parasitic phase begins almost immediately if prey is available. During transformation there are such changes as: length and weight decrease; oral hood transforms into sucking disc; rasping tongue develops; strong, sharp teeth develop in disc and on tongue; deeply embedded, rudimentary eyes appear at surface as large, functional eye; dorsal fins become more pronounced; body colour changes from pale brown to blue-grey above and silver-white below.

Downstream movement of the newly transformed adults to a lake or the sea takes place in a lesser peak in October and November, in small numbers through the winter, and with the major peak in the following April, and seems to be associated with onset of increased stream flow.

As parasites in the larger bodies of water, growth is rapid during the 12–20 months of adult life. Growth rate over the first 7 months of this period, expressed as length range and mean size in various months in the Great Lakes, from Applegate (1950), is as follows:

	Mean TL		Range TL	
	(inches)	*(mm)*	*(inches)*	*(mm)*
June	8.2	208	5.5–11.6	149–295
July	10.0	254	6.7–15.5	170–394
Aug.	12.6	320	9.5–16.8	241–427
Sept.	13.6	345	9.9–20.4	251–518
Oct.	16.0	406	13.6–19.3	345–490
Nov.	16.7	424	14.7–18.5	373–470
Dec.	17.3	439	12.8–21.1	325–536

Size ranges of samples in fall months are extended by the arrival of newly transformed adults of the next year-class. Little growth appears to take place over the winter and feeding probably ceases sometime in this period, during which sexual maturity commences, although they have been seen attached to fish caught under the ice. Simple attachment is, however, no indication of feeding. Lampreys are known to attach themselves to inanimate objects such as boats, apparently for passive transport as do sharksuckers, Echeneidae. In the spawning run of the following spring the adults will range in total length from 12.0 to 22.8 inches (305–579 mm).

Maximum size of landlocked sea lampreys appears usually to be approximately 20 inches (528–536 mm) and 363 grams but can reach 30 inches (762 mm) (MacKay and MacGillivray 1949) and anadromous adults are known as large as approximately 34 inches (860 mm) (Vladykov 1949a).

Knowledge of the habitat of the adult is scanty. In the Great Lakes it is presumed by the known habitat of the hosts on which they are taken at different times in the year, that they migrate first to deep water, moving shoreward as they grow, and that in fall they are in shallow water. They have been taken over a depth range of 2.5–540 feet in Lake Huron. It is assumed that in the sea most remain close to shore in shallow water. They have, however, been taken on the Grand Banks and as deep as 547 feet (Bigelow and Schroeder 1948).

The ammocoetes are sedentary filter feeders and their midsummer diet consists largely of minute plant and animal material such as: filamentous green algae, detritus, pollen, diatoms, desminds, and protozoans (Creaser and Hann 1929). They can withstand extremely long periods of starvation. The adults live as external parasites of fishes in fresh water, and of fishes and possibly other aquatic vertebrates in the ocean. As soon after transformation as a host is available they attach themselves to it by means of the suctoral disc, usually low on the body between the positions of the paired fins in the case of a fish. The teeth of the tongue rasp a hole in the skin of the host and its body fluids and blood are consumed. A secretion, called lamphredin, produced by a pair of buccal glands, assists by (*a*) preventing or slowing coagulation of the host's blood and (*b*) a cytolotic action that breaks down muscle tissue to a state ingestible by the lamprey. Usually the parasite penetrates only part way through the body wall but at times they penetrate the wall and consume eggs or penetrate the gut and take the gut content of the host (Moffett 1966). Length of time feeding on a host varies with lamprey size. Experimental results were from 220.2 hours for newly transformed lampreys to 38.7 hours for lampreys 12.9 inches (328 mm) in total length (Lennon 1954). If concentrations of ammocoetes migrating downstream encounter fish in the estuary as many as four can become attached to the same host. Among the species the sea lamprey attacks in fresh water are: lake trout, lake whitefish, chubs (*Coregonus* spp.), white sucker, longnose sucker, redhorse, yellow perch, rainbow trout, burbot, channel catfish, northern pike, carp, and walleye. The anadromous lampreys are reported to have attacked Atlantic mackerel, American shad, Atlantic cod, haddock, American pollock, squirrel hake, Atlantic salmon, basking shark, Atlantic herring, swordfish, sturgeons, and American eel (Bigelow and Schroeder 1948).

Lampreys are particularly abundant, concentrated, and vulnerable as blind spawners in shallow, freshwater streams. They are most extensively preyed on by several species of gulls, by various herons, hawks, owls, and bitterns, water snake, racoon, muskrat, mink, weasel, fox, and by other fishes such as: northern pike, walleye, brown trout, and Atlantic cod. Minnows of the genera *Notropis* and *Rhinichthys* are known to feed on lamprey eggs as they are being laid; probably other small stream fishes do also. The 90% mortality between deposition of eggs and ammocoete emergence is the most serious mortality factor affecting recruitment. Next is drying of stream areas containing ammocoetes and prespawning predation on adults. Adult sea lampreys may compete for host fishes and for spawning sites with the silver lamprey, *Ichthyomyzon unicuspis*, but since they are larger and more aggressive they have a distinct advantage. Ammocoetes may compete with other lampreys for suitable areas in which to burrow, and for food.

Parasites of the lamprey, too extensive to list here, and references to publications on the parasites of this species were given by Applegate (1950), McLain (1952), Bangham (1955), Hoffman (1967), Wilson and Ronald (1967), and Ronald and Wilson (1968).

Relation to man This species has more direct and indirect relation to man than any other species of North American lamprey. Directly, its importance as food to man is far greater in Europe, where it has long been considered a delicacy, than it is in North America. It is said King Henry I of England died of a surfeit of it. In North America, it is popular only with people newly arrived from Europe. Attempts to popularize it have failed largely because of its appearance and the fact that in the spring adult migrations, when it is readily available in large numbers and easily caught, its physiological state renders it not very palatable. In Europe lampreys for food are caught in winter and grilled, fried, marinated, steamed, salted, or canned. The sea lamprey was at one time an important food along the Connecticut River and was salted down in barrels for winter use (Vladykov 1949a), or sold for $5.00 per hundred fish. In 1961 the only North American commercial fishery for sea lampreys was operated by a Mr T. Roze on the Saugeen River at Southampton, Ont. Lampreys were caught in willow baskets set in a weir, roasted, canned, and sold in Toronto (Thomas 1961).

Sea lamprey ammocoetes are sold as bait for other fishes on the east coast of the United States and possibly in Quebec.

In the Great Lakes the sea lamprey has been known to attach itself to long distance swimmers but is quickly and easily dislodged. It will not attach itself to humans until long submersion has lowered skin temperature. At this point it will attach itself and begin to rasp. No human has apparently been willing to see if it would continue to the point of feeding. It would no doubt do so, as the Pacific lamprey, *Entosphenus tridentatus*, has been recorded found attached to warm-blooded, marine mammals.

Its indirect relation is more significant in its destruction of fishes economically and aesthetically important to man. Prior to its entry into the upper Great Lakes its destruction of fishes in the Finger Lakes led to comment about the necessity for controls. In the sea it is rarely seen and the destruction of fishes there goes unnoticed; in Lake Ontario some natural control must have kept its depredations below the level demanding attention. It was not until this species made its way into lakes Huron, Michigan, and Superior, between 1936 and 1946, that the catastrophic results of its parasitism were seen. It developed tremendous populations in very short periods and quickly decimated, or contributed significantly to the decline of one after another of the stocks of important commercial fishes such as lake trout and whitefish in these lakes. Before the lamprey, the combined annual United States and Canadian catches of lake trout in the three upper lakes was approximately 15 million pounds. By the early 1960's the catch had fallen to 300 thousand pounds. The catch in Lake Huron fell from 3.4 million pounds in 1937 to virtual failure of the fishery in 1947. The United States catch in Lake Michigan fell from 5.5 million pounds in 1946 to 402 pounds in 1953. The Lake Superior catch dropped from an average of 4.5 million pounds to 368 thousand pounds in 1961. This decline was probably not due solely to the sea lamprey, but the role of the lamprey is easy to imagine when you consider the following: (1) up to 85% of various species of fishes not killed by lampreys had been attacked one to five times and had somehow survived the loss of blood and opportunity for secondary infection; (2) the average lamprey destroys 19.6 pounds of fish during its parasitic period (Parker and Lennon 1956) and up to 25,000 adults have been counted entering a single river.

Attempts to control lamprey parasitism of fishes of the Great Lakes began in the late 1940's. It progressed from studies of the biology of the lamprey to mechanical weirs, then to electrical barriers to block upstream migration of spawners, and finally, to the use of a selective poison to kill the ammocoetes in their burrows. Attempts to control the sea lamprey and rehabilitate the fishes led to the forming, in 1955, of the International Great Lakes Fishery Commission, to the large scale hatchery rearing of lake trout and to the selective breeding and rearing of a then little-known hybrid between the lake trout and the brook trout now called the *splake*. It was hoped that this latter fish would use areas of the lakes where it might avoid the lamprey and mature fast enough to spawn at least once before it could be destroyed by lamprey parasitism.

The control measures, in particular the use of the chemical lampricide TFM, have reduced lamprey numbers by over 90% of the 1961 high. The control is, however, a constant and costly one as the level of lamprey numbers now is about equal to what it was when controls were first initiated in the early 1950's.

The public and scientific literature on the biological and socioeconomic consequences of the sea lamprey invasion of the Great Lakes is voluminous. The scientific literature is found primarily in the publications of the Fisheries Research Board of Canada, the Canada Department of Fisheries, the U.S. Fish and Wildlife Service, the Transactions of the American Fisheries Society, and the International Great Lakes Fishery Commission.

Nomenclature

Petromyzon marinus	— Linnaeus 1758: 230 (type locality European seas)
Petromyzon Americanus	— Perley 1852: 225
Petromyzon nigricans	— Provancher 1876: 262
Petromyzon concolor	— Wright 1892: 439
Petromyzon marinus unicolor	— Halkett 1913: 11
Petromyzon marinus var. *dorsatus* Wilder	— Huntsman 1917: 25
Petromyzon marinus unicolor (DeKay)	— Dymond 1922: 60

Etymology *Petromyzon* — sucker of stone; *marinus* — of the sea.

Common names Sea lamprey, great sea lamprey, landlocked sea lamprey, lake lamprey, lamprey, lamprey eel, lamper eel. French common name: *lamproie marine.*

Suggested Reading – Petromyzontidae

Applegate, V. C. 1950. Natural history of the sea lamprey, *Petromyzon marinus*, in Michigan. U.S. Fish Wildl. Serv. Spec. Sci. Rep. Fish. 55: 1–237.

Bardack, D., and R. Zangerl. 1968. First fossil lamprey: a record from the Pennsylvanian of Illinois. Science 162: 1265–1267.

Berg, L. S. 1931. A review of the lampreys of the northern hemisphere. Akad. Nauk SSSR Zool. Mus. Ann. 32: 87–116 + 8 plates. Leningrad.

Buchwald, D. G. MS 1968. The Arctic lamprey of Great Slave Lake, N.W.T. M.Sc. Thesis. Univ. Alberta, Edmonton, Alta. 84 p.

Carl, G. C., W. A. Clemens, and C. C. Lindsey. 1967. The fresh-water fishes of British Columbia. B.C. Prov. Mus. Handb. 5: 192 p.

Clemens, W. A., and G. V. Wilby. 1961. Fishes of the Pacific coast of Canada. 2nd ed. Fish. Res. Board Can. Bull. 68: 443 p.

Gage, S. H. 1928. The lampreys of New York State — life history and economics, p. 158–191. *In* A biological survey of the Oswego River System. Suppl. 17th Annu. Rep. N.Y. Conserv. Dep. 1927: 248 p.

Hardisty, W. M., and I. C. **Potter** (ed.) 1971. The biology of the lampreys, Vol. I. Academic Press, N.Y. 423 p.

Hubbs, C. L., and M. B. **Trautman**. 1937. A revision of the lamprey genus *Ichthyomyzon*. Univ. Mich. Mus. Zool. Misc. Publ. 35: 1–109.

Hussokof, L. 1913. Sea lampreys and their nests. Amer. Mus. J. 13: 323–325.

Lawrie, A. H. 1970. The sea lamprey in the Great Lakes. Trans. Amer. Fish. Soc. 99: 766–775.

Lennon, R. E. 1954. Feeding mechanism of the sea lamprey and its effect on host fishes. U.S. Fish Wildl. Serv. Fish. Bull. 98, vol. 56: 247–293.

Moffett, J. W. 1966. The general biology of the cyclostomes with special reference to the lamprey, p. 255–262. *In* Phylogeny of Immunity. Univ. Florida Press, Gainesville, Fla.

Newth, H. G. 1930. The feeding of ammocoetes. Nature 126(3168): 94–95.

Parker, P. S., and R. E. **Lennon**. 1956. Biology of the sea lamprey in its parasitic phase. U.S. Fish Wildl. Serv. Res. Rep. 44: iii + 32 p.

Pletcher, F. T. MS 1963. The life history and distribution of lampreys in the Salmon and certain other rivers in British Columbia, Canada. M.Sc. Thesis. Univ. British Columbia, Vancouver, B.C. 195 p.

Regan, C. T. 1911. A synopsis of the marsipobranchs of the order Hyperoartii. Ann. Mag. Natur. Hist. 8th ser. vol. 7: 173–204.

Ronald, K., and K. A. **Wilson**. MS 1968. A check list of the parasites of the order Petromyzontiformes (lampreys). Fish. Res. Board Can. Tech. Rep. 48: 23 p.

Surface, H. A. 1898. The lampreys of central New York. Ext. U.S. Fish. Comm. Bull. 1897: 209–215 + pl. 10, 11.

Vladykov, V. D. 1949. Quebec lampreys (Petromyzonidae). 1. List of species and their economical importance. Dep. Fish. Prov. Que. Contrib. 26: 67 p.

1950. Larvae of eastern American lampreys (Petromyzonidae). I. Species with two dorsal fins. Natur. Can. 77: 73–94.

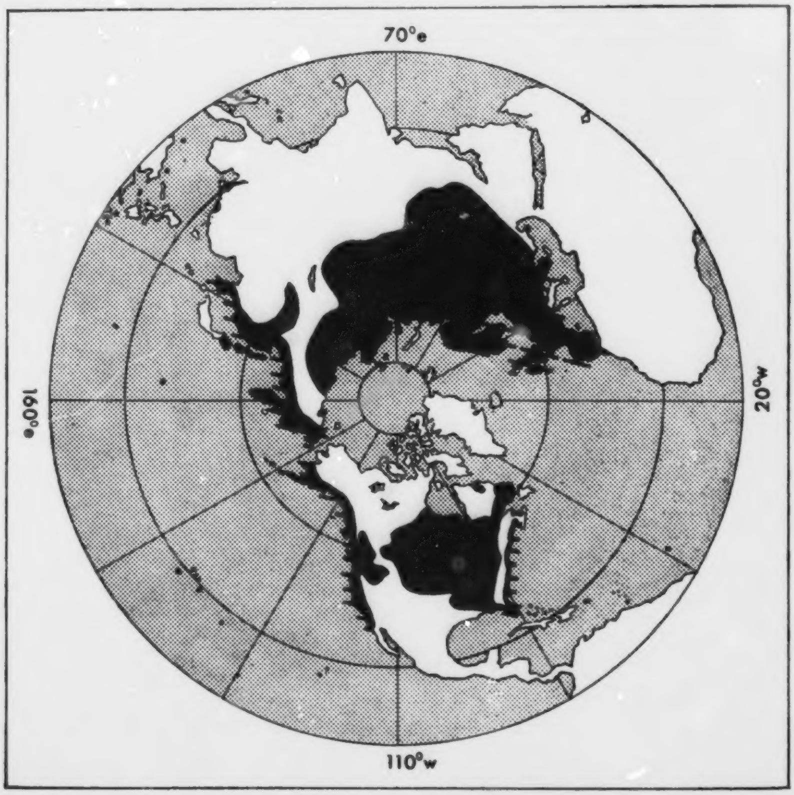
Wigley, R. L. 1959. Life history of the sea lamprey of Cayuga Lake, New York. U.S. Fish Wildl. Serv. Fish. Bull. 154, vol. 59: 561–617.

THE STURGEONS AND PADDLEFISHES—
Order Acipenseriformes (Chondrostei)

Body heavy and almost cylindrical; tail heterocercal but in some so even and deeply forked as to appear homocercal. Skeleton, including the cranium, cartilagineous. Some superficial bones of the head and pectoral girdle ossified. Upper jaw does not articulate with the skull. Paired fins well developed; pelvics abdominal and without true spines. Skin appears largely naked except for rows of large plates or bucklers in some species but in most species (at least in the young) the skin is variously covered with denticles; axes of fins of some species with spinelike scales called fulcra. Vertebrae without centra. Notochord persistent, extending into the upper lobe of the tail.

These fish inhabit temperate, marine and fresh water, and the marine forms spawn in fresh water.

The order consists of one fossil family, and 2 living families, Acipenseridae and Polyodontidae, that contain 6 genera. The extinct family Chondrosteidae is known from the Lower Jurassic to the Lower Cretaceous.



World Distribution of the Sturgeons

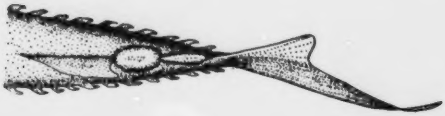
STURGEON FAMILY — Acipenseridae

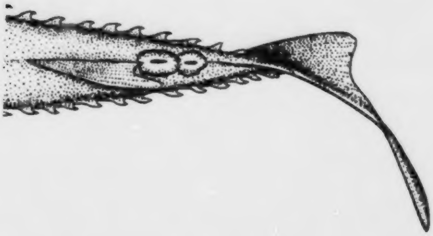
The sturgeons are heavy, subcylindrical fishes with extended, hard snouts; and a ventral, protrusible mouth preceded by 4 barbels. Prominent body covering of large, bony scutes in 5 rows, 1 dorsal, 2 lateral, and 2 lateroventral. Sharp and obvious in the young, these plates become smoother with age and in some species gradually disappear by absorption. The rest of the skin appears naked but has small patches of denticles. The head is covered by bony plates. The unpaired fins are preceded by fulcra; the first ray of the pectoral fin is enlarged and ossified. The tail is broad and heterocercal; the dorsal and anal fins are approximately opposite and far back on the body. The 4 gills, and, in some, an accessory pseudobranch, are covered by an expanded subopercle bone. The opercle bone and branchiostegal rays are absent.

The sturgeons are anadromous, and freshwater fishes of the northern hemisphere known from the Upper Cretaceous. The family includes 23 species in 4 genera: *Huso*, 2 species, Pliocene to Recent; *Acipenser*, 16 species, Upper Cretaceous to Recent; *Scaphyrhynchus*, 2 species; *Pseudoscaphyrhynchus*, 3 species.

KEY TO SPECIES

1 **Obvious plates, other than fulcra, between anal fin and caudal fin (*top figure*), and between dorsal fin and caudal fin (*bottom figure*) 2**





No obvious plates behind dorsal or anal fin other than fulcra; 6–9 plates, mainly in 2 rows, between anus and anal fulcra; dorsal plates 11–14; lateral plates 38–48; to 20 feet and 1387 pounds. .... WHITE STURGEON, *Acipenser transmontanus* (p. 96)

2 One large plate between anal fin and caudal fulcrum 3

Four smaller plates usually as 2 pairs, between anal fin and caudal fulcrum, first pair may overlap base of anal fin, second pair may look like one plate; 6–9 plates, mostly in pairs, behind dorsal fin; dorsal plates 7–16; lateral plates 24–35; usually to 10 feet and 300 pounds. .... ATLANTIC STURGEON, *Acipenser oxyrhynchus* (p. 92)

3 Distance from tip of snout to line of barbels equal to, or slightly less than, one-half the distance from tip of snout to anterior edge of mouth, lip excluded; snout to barbels no more than 1.5 times distance from posterior margin of mouth, lips excluded, to isthmus; gill rakers 22–40 4

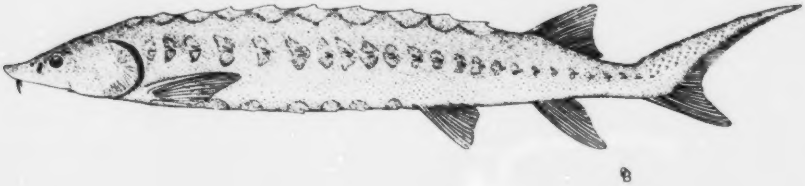
Distance from tip of snout to line of barbels more than one-half the distance from tip of snout to anterior edge of mouth, lip excluded; snout to barbels over twice the distance from posterior edge of mouth, lip excluded, to isthmus; gill rakers 18–20; dorsal plates 8–11; lateral plates 23–30; to 7 feet and 350 pounds. .... GREEN STURGEON, *Acipenser medirostris* (p. 90)

4 Anal fin rays 25–30; insertion of anal fin plainly behind insertion of dorsal fin; gill rakers 25–40 but usually 32–35; caudal peduncle longer, tip of anal fin reaching only to anterior edge of caudal fulcral plate; dorsal plates 9–17; lateral plates 29–42; to 3–5 feet and 310 pounds. .... LAKE STURGEON, *Acipenser fulvescens* (p. 82)

Anal fin rays 19–22; insertion of anal fin opposite insertion of dorsal fin; gill rakers 22–29; caudal peduncle shorter, tip of anal fin reaching origin of caudal fin; dorsal plates 8–13; lateral plates 22–33; to 36 inches and 9 pounds. .... SHORTNOSE STURGEON, *Acipenser brevirostrum* (p. 80)

SHORTNOSE STURGEON

Acipenser brevirostrum Lesueur



Description A moderate-sized, heavy-bodied fish, small compared to other sturgeons. Usual length 36 inches (912 mm). Body pentagonal in cross section. Head short, 22–28% of fork length, snout short, blunt, rounded, 70% of postorbital length in adults 15–28 inches (381–711 mm) but longer than postorbital length in young; mouth wide, width (excluding lips) 69–81% of interorbital width, no teeth; 4 barbels in front of mouth, somewhat closer to snout than to mouth; gill rakers moderately long, triangular, 22–29 (mean = 25.5) on first arch. Fins: single dorsal far back, opposite anal, trailing edge crescentric, 38–42 rays; caudal markedly heterocercal, lower lobe shorter and broad, upper long and pointed, no notch at lower tip, difference between fork length and total length is 11% of fork length; caudal peduncle short, tip of depressed anal reaching base of caudal fin; anal base about 60% of dorsal fin base, trailing edge emarginate, 19–22 rays; paired fins with heavy, ossified first ray, pelvics abdominal, far back, pectorals large. The body is not covered with scales but with patches of minute denticles and with rows of large, bony plates, scutes, or bucklers, 8–13 dorsal plates, 22–33 lateral plates, 7–11 ventral plates, at least 2 plates between dorsal fin and caudal fulcrum, at least one between anal fin and caudal fulcrum, usually a single row (sometimes 2 + 1) of plates between vent and anal fulcrum (preanal plates); no lateral line. Skeleton is cartilagineous except for membrane bones of skull, jaws, and pectoral girdle; vertebral centra absent, notochord persistent (largely from Vladykov and Greeley 1963).

Colour Body colour dark brown to nearly black on head, back, and sides to level of lateral plates, lighter brown to yellowish below, lower edge of head and body and entire ventral surface and barbels white; all fins pigmented but paired fins outlined in white; plates much paler and lateral plates obvious against dark background; viscera black, peritoneum pigmented; young with black blotches. Preserved specimens acquire a green colour in the skin, especially ventral surface and lower sides of head (Vladykov and Greeley 1963). A good colour illustration of an adult male was given (plate no. 2) in Greeley (1937).

Distribution Restricted to the eastern seaboard of North America from the Saint John River in New Brunswick to the St. Johns River of eastern Florida. Nowhere abundant now. It was probably most abundant, in the past, in rivers from the Connecticut to the Potomac.

In Canada it is known only from the Saint John River, upstream to Gagetown, where it is apparently more abundant than previously thought. Numbers of individuals in recent collections indicate the probable presence of a spawning population there. Records of the shortnose sturgeon in the St. Lawrence River were erroneous and based on *A. fulvescens* and *A. oxyrhynchus*.

Biology Spawning takes place in the spring, in the middle reaches of large tidal rivers from April to early June, depending on location. Adults apparently return to a parent stream. The eggs are dark brown in colour, small, and less numerous per pound of fish than in other sturgeons.

As with most sturgeons very little is known of the spawning and early life history, the young are rarely seen. Apparently the smallest specimen known was one 7.3 inches (185 mm) total length from North Carolina (Vladykov and Greeley 1963). Growth expressed as age–length relation for Hudson River shortnose sturgeon between 3 and 14 years (= no. of winters) was given by Greeley (1937) as follows:

Age	Range TL		Mean TL	Mean wt
(years)	*inches*	*(mm)*	*inches(mm)*	*(oz)*
3	–	–	21.9(556)	47.0
4	–	–	21.2(538)	31.0
5	21.9–23.7	(556–602)	22.6(574)	41.8
6	23.3–28.0	(592–711)	25.7(653)	55.3
7	22.9–31.4	(582–797)	26.1(663)	59.7
8	22.6–25.5	(574–648)	24.2(615)	51.3
9	31.4–33.6	(797–853)	32.5(827)	119.0
10	–	–	24.4(620)	87.5
11	–	–	26.9(683)	78.5
12	–	–	32.8(834)	134.5
13	–	–	34.8(885)	143.0
14	–	–	30.5(775)	116.0

However, Magnin (1963a) gave an account for the age–length relation of older sturgeon in the Saint John River as follows:

Age	TL	
(years)	*(inches)*	*(mm)*
14	28.7	730
15	31.5	800
16	27.2	690
17	30.3	770
18	31.1	790
19	29.5	750
20	32.3	820
22	30.3	770
23	34.6	880
27	31.5	800

These data indicate a probable maximum total length in the Hudson River of 34.8 inches (885 mm) for 14-year-old fish, weighing 8 pounds 15 ounces. The largest on record is an individual 39.5 inches (997 mm) total length from the Connecticut River. Canadian specimens from the Saint John River are usually 18–24 inches (457–610 mm) in total length, but have been taken as large as 31.5 inches (870 mm) total length. More recently specimens up to 4 feet (122 cm) from the Saint John River have been reported but not authenticated. In early March 1972 a female specimen 42.9 inches (109 cm) in total length and 13.25 pounds in weight was captured in Grand Lake, N.B., near the mouth of the Jemseg River.

This is a slow growing species. Prior to 1963 the maximum age was thought to be 15 years. Magnin extended this to at least 27 years and possibly 30 years. Magnin's (1963a) ages overlap and fit conveniently to the upper end of Greeley's data. Magnin interpreted age from pectoral fin rays, Greeley from otoliths. If their ages are correct, either the larger fish were not present in the Hudson River or were missed by the gear, or the Saint John River sturgeon grow much more slowly and live almost twice as long.

Growth rate of the shortnose sturgeon in early years is apparently similar to that of the Atlantic sturgeon, *A. oxyrhynchus*, so part of the difference in ultimate size may result from the greater tendency of the shortnose sturgeon to remain longer in rivers where food is less available. This species assumes adult characteristics at 2 feet (610 mm) in length.

Sexual maturity is achieved in U.S. populations by males at approximately 20 inches (508 mm) total length and females at approximately 24 inches (610 mm) and 3–5 pounds. They are capable of spawning more than once but Canadian fish may not be able to do so unless they achieve maturity at a smaller size than the more southerly populations.

This species is seen most often in large tidal rivers but is also taken in brackish and salt water. Captures in the Gulf of Maine indicate that it goes to sea and travels distances from the parent stream, but it is not so strongly migratory as other species.

The protrusible tube mouth obviously adapts sturgeons to feeding off the bottom. Hudson River specimens had eaten sludgeworms, chironomid larvae, small crustaceans, and plants.

Nothing is known of the predators of the larger fish. Even the young may be adequately protected from predation by their plates. Young and adult alike compete for food with other bottom-feeding fishes such as suckers, but their random, suctorial feeding off the bottom may have some advantage over the many species of fishes that browse on individual bottom organisms in the same turbid rivers. The main limitation would appear to be their extreme slow growth and late maturation.

Relation to man The flesh is of good quality, the eggs, although not great in number, are suitable for caviar. The present small size and low availability of this species make it of only incidental commercial importance today. In the 1800's this species was apparently preferred by fishermen in the Delaware River to the larger Atlantic sturgeon, as it commanded a higher price. In the early 1900's it was taken with gillnets and by hook and line in the various rivers. It is possible that this species, as well as the Atlantic sturgeon, is still taken infrequently in drift gillnets set for American shad, *Alosa sapidissima*, in east coast rivers of the U.S. Since they are small, commercially unimportant, and destructive to nets, they are probably destroyed when taken. Commercial fishermen at Long Reach, Saint John River, N.B. say they catch about equal numbers of shortnose and Atlantic sturgeons. These are apparently marketed in New York City.

The shortnose sturgeon is on the list of rare or endangered Canadian fishes. This may reflect the lack of knowledge of its true abundance or that the total Canadian population may be in an endangered habitat.

Nomenclature

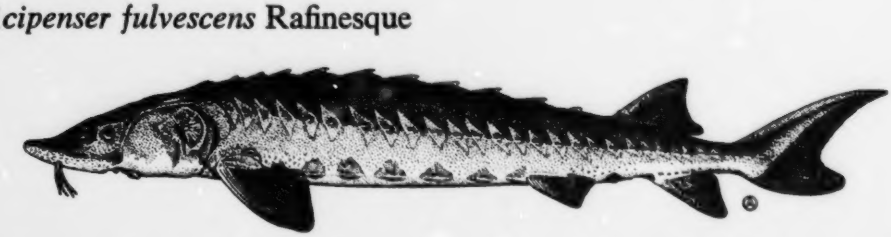
Acipenser brevirostrum — LeSueur 1818c: 390 (type locality Atlantic coast)
Acipenser brevirostris LeSueur — Richardson 1836: 278

Etymology *Acipenser* — an old world name for sturgeon; *brevirostrum* — short snout.

Common names Shortnose sturgeon, shortnosed sturgeon, small individuals called pinkster in New York. French common name: *esturgeon à museau court.*

LAKE STURGEON

Acipenser fulvescens Rafinesque



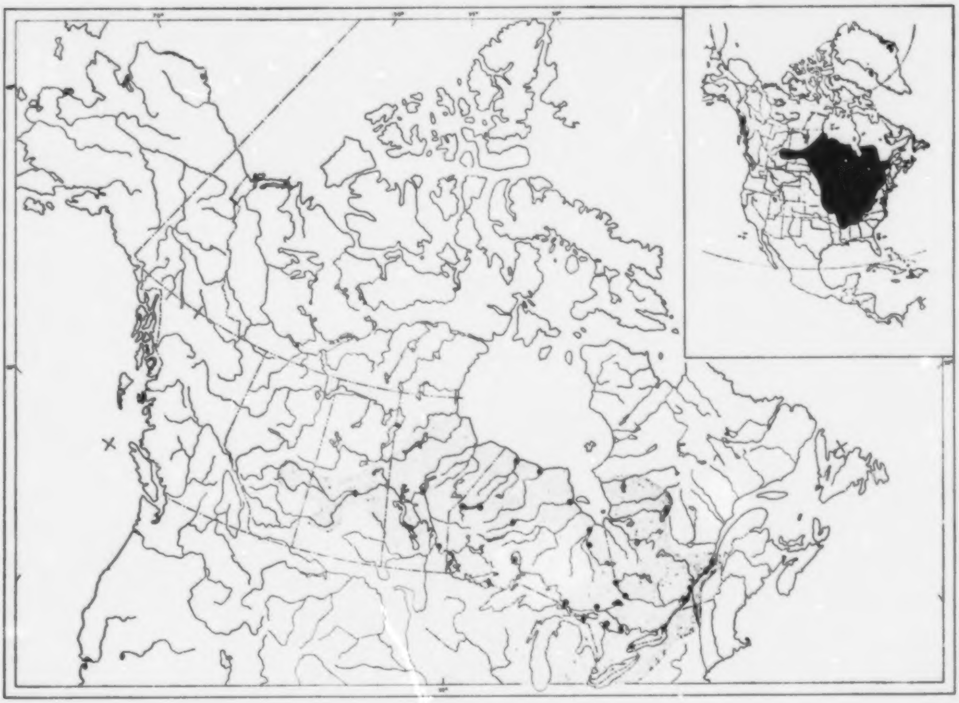
Description Heavy, torpedo-shaped body, markedly pentagonal in cross section in young but round in adults. As a result of minimum total length, weight, and mesh regulations, sturgeon seen today are usually 3–5 feet (91.5–142.5 cm) in total length and 10–80 pounds in weight. Most notable characteristic of the young is the bony plates or shields in 5 rows. Head appears long in young, shorter in adults due to relative length of snout, head length usually 24% of fork length in specimens 16–17 inches (400–700 mm) fork length. Snout length in individuals less than 19 inches (500 mm) fork length is greater than postorbital length, but less than postorbital length in larger individuals; skull broad, interorbital width 21.6–40.0% of head length, no fontinella; eyes midway between mouth and barbels, appear small in very large specimens. The characteristic protrusible, suctorial mouth is ventral, far back, posterior to the eyes, and large, its width (excluding lips) 66–93% of interorbital width; no teeth; gill rakers 25–40, but usually 32–35, short and blunt; 4 moderately short, prominent, ventral barbels well in advance of mouth. Fins: a single, moderately large dorsal, far back near caudal, 35–40 stiff rays, posterior edge only slightly falcate; caudal heterocercal, average difference between total length and fork length 9% of fork length, no notch in ventral edge of tip of upper lobe, lower lobe broad and rounded; anal under dorsal, base shorter than dorsal, tip rounded, 25–30 stiff rays; pelvics close to anal, approximately the size of the anal, trailing edge emarginate; pectorals low, large, and round at the tip, first ray ossified. No simple scales, body largely covered by minute, dermal denticles on a very tough skin; prominent rows of bony plates or shields, dorsal row 9–17, lateral row 29–42, ventral row 7–12, plates prominent, sharp, adjacent plates touching in very young, separated and more rounded or inconspicuous in larger individuals, 1 or more obvious plates between all posterior fins and between anus and anal fin. Vertebrae cartilagineous, centra absent, notochord persistent (partly from Vladykov and Greeley 1963). Plate number and arrangement were treated in detail by Vladykov and Beaulieu (1946).

Colour In young less than 12 inches (300 mm) total length, two large black blotches on upper surface of snout and between dorsal and lateral shields, one opposite base of pectoral fin, one below dorsal fin; smaller black spots on head, back, sides, and caudal peduncle; large blotches disappear when individuals reach 24 inches (610 mm) total length; larger individuals olive-brown to grey on back and sides, white below. Dorsal and lateral shields are the same colour as the body, lower surfaces of ventral shields white. Fins dark brown or grey. In preserved specimens lower surfaces green. Intestines dark, nearly black, swim bladder and fat grey, peritoneum clear to slightly pigmented (Vladykov and Greeley 1963). A good colour illustration is available in Vladykov (1955b). *See* colour illustration, this text, facing p. 90.

Systematic notes Roussow in 1955 described two morphae of this species *A. f. acutirostris*, the brown or lake sturgeon, and *A. f. obtusirostris*, the black or rock sturgeon.

Distribution In larger rivers and lakes from the St. Lawrence River near Cap Brulé to Hudson Bay and west to the North Saskatchewan River in Alberta, south through Lake Champlain, the Mississippi River to the Tennessee River in Alabama and in northern Mississippi. From lakes Winnipeg and Manitoba south through the eastern Dakotas, northeastern Nebraska and Kansas to eastern Missouri and Arkansas (Vladykov and Greeley 1963).

In Canada, Harkness and Dymond (1961) reported it from Hudson–James Bay as far north as Fort George River on the east and Seal River on the west; in North Saskatchewan River of Alberta almost to Edmonton; South Saskatchewan River of Saskatchewan; Lake Winnipeg, Assiniboine and Red rivers of Manitoba, less abundant to rare in lakes Manitoba and Winnipegosis; all of the Hudson Bay and Great Lakes drainages of Ontario, including all the Great Lakes; east to Cap Brulé or freshwater termination in the St. Lawrence River. Vladykov and Greeley (1963) suggested it may be in Labrador. It



is taken only occasionally from brackish water of the St. Lawrence River, and at Moose Factory on James Bay; and no sea residence known (Vladykov and Greeley 1963). Harkness and Dymond (1961) gave a very detailed account of the distribution in North America.

Biology The lake sturgeon spawns from early May to late June depending on locality. Optimum spawning temperature appears to be between 55.4° F (13° C) and 64.4° F (18° C). Sturgeon generally leave lakes on the spawning migration not long after the spawning rivers are free of ice and sometimes move under the ice. Migration seldom, if ever, exceeds 250 miles (Vladykov 1955b) but feeding ceases for the whole of the spawning period. They spawn in depths of 2–15 feet and in areas of swift water or rapids often even at the foot of low falls that prevent further migration. Richardson (1836), who spent the winter of 1819–20 in northern Saskatchewan, reported that the great rapid (Grand Rapids) of the North Saskatchewan River, where it empties into Lake Winnipeg, appeared quite alive with sturgeons in June. Where suitable spawning rivers are not available, such as in the lower Great Lakes, sturgeon are known to spawn in wave action over rocky ledges or around rocky islands. Males reach the spawning grounds first and the fish congregate before spawning temperatures are reached. Many observations of sturgeon rolling near the bottom and then leaping completely out of the water to fall back with considerable splash and noise have been recorded during spawning or the prespawning congregation.

The females are in spawning condition for only a brief period and females with free-running eggs are seldom seen. During spawning they lie in groups of two or three, one or two males to each female; the males are much smaller. No nest is constructed and the adhesive eggs are scattered and adhere to rocks and logs. All the eggs are not shed at once but probably over a period of one or more days. The ripe eggs are black in colour and 2.7–3.5 mm in diameter. Roussow (1957) gave coloured illustrations of ovarian maturation stages. After maturation, egg number increases with the weight of the female, but is variable in fish of the same weight; one can have twice as many eggs as another. Calculated total egg numbers and number per pound of fish as given by Cuerrier were quoted in Harkness and Dymond (1961) as follows:

Female wt(*lb*)	Total eggs	Eggs per lb sturgeon
11.5	49,835	4333
36.0	184,913	5136
57.0	323,817	5681
79.0	370,910	4695
112.0	667,472	5960

Cuerrier (1949) gave the minimum and maximum calculated number of eggs in lake sturgeon as 107,510 and 885,360. Calculated egg numbers have often been extrapolated to indicate that 200-pound females could carry as many as 3,000,000 eggs.

At temperatures of 60°–64° F (15.6°–17.8° C) some eggs hatched in 5 days and all had hatched by 8 days. The young, 8 mm long, are nourished by a large yolk sac for 9–18 days. By 2 weeks the young are miniatures of the adult and the paired fins are well developed and by 16 days they are approximately 21 mm long at which time they begin to feed. By September of the first year they have grown to 4.8 inches (123 mm) total length. Growth is somewhat slower from this point and the age–length and age–weight relations, as given by Harkness (1923) for Lake Nipigon, is shown in the following table. From this table it can be seen that, in the first 5 years, sturgeon increase rapidly in length but little in weight. Between 5 and 15 years, there is a decrease in rate of length increment whereas weight increases at a faster rate. After 20 years and the onset of sexual maturity, rate of increase in length is even slower but more uniform and the increase in weight becomes more rapid.

Age	TL		Wt
	(*inches*)	(*cm*)	(*lb*)
1	7.7–11.1	19.7–28.1	0.1–0.2
2	11.8	30.0	0.3
3	13.0–14.4	33.0–36.5	0.3–0.4
4	15.9–19.1	40.3–48.4	0.8–1.1
5	19.0–20.5	48.2–52.0	1.1–1.3
6	21.3–21.7	54.2–55.1	1.5–1.7
7	22.0–23.8	56.0–60.5	1.9–2.3
8	23.7–23.8	60.2–60.5	2.1–2.4
9	22.1–24.8	56.1–62.9	1.7–2.7
10	23.6–29.4	60.0–74.7	2.1–4.1
12	30.4	77.2	5.1
13	29.2	74.2	4.2
15	30.1–31.3	76.5–79.6	4.0–5.7
17	34.3	87.3	6.5
18	35.0	89.0	6.4
19	35.6	90.5	9.8
22	35.0	89.0	8.4
25	39.6	100.0	12.0
37	53.8	136.0	42.0
38	58.3	147.5	45.0
40	52.4	132.4	29.0
47	63.0	165.5	64.0
50	61.5	156.0	50.0

Harkness (1923) tabulated this data as the number of summers, i.e., third summer equals 2 years of age.

The interpretation of age in sturgeon, from otoliths, opercula, and pectoral fin ray sections has not been easy or uniform. In a fish with such a long life span and variability of growth rate in different environments, age of older fish, accurate within 5 or 6 years, is a most difficult decision. Since this is so, tables of comparative age–length relation for various localities are of limited value. Harkness and Dymond (1961) gave graphic comparison for populations in Quebec, Ontario, Wisconsin, and Manitoba. Consequently, age at sexual maturity, age at first spawning, and interval between successive spawnings has long been a debatable point. In this large, slow-growing species, sexual maturity is very late. In 1923 Harkness felt that sexual maturity was not reached by sturgeon in Lake Nipigon until age 22 or later. Harkness and Dymond (1961) gave the following comparison of age at sexual maturity for various locations:

	Males	Females
Ottawa River, Que.	19–20	26
Lake St. Francis (St. Lawrence R.)	15	23
Quebec	12–19	14–23
Nelson River, Man.	15–20	25–33

Roussow (1957) considered that maturity was reached by 8–13 years but that first spawning took place at 12–19 years for males and 14–23 years for females. Magnin (1966a) estimated that sexual maturity was reached by females in northern Quebec at 20–23 years, 35.4–39.6 inches (90–100 cm) total length, and 9.5–19.8 pounds weight. For males he gave 18–20 years, 33.4–37.4 inches (85–95 cm) total length and 8.6–11.4 pounds weight.

Roussow in 1957 estimated as did most earlier authors that interval between spawnings only sometimes increased with age, and was 4–7 years in males and as high as 7–9 years in females. With more and more refinement of the aging techniques, this interval has decreased so that, in 1966, Magnin (1966b) felt that, depending on locality south to north, females spawned every 4–6 years and males every year to every 2 or 3 years. Total length at first spawning varies in Canada from 30 to 40 inches (76.2–101.6 cm) for males and 33 to 47 inches (83.9–119.5 cm) for females.

As with all interpretations involved with age, the maximum age of lake sturgeon is open to question. Females do live longer than males. Magnin (1966a) gave 55 years as the usual maximum age for males and 80 years for females in Quebec, stating that, in the oldest fish, there were only 4 males over the age of 55 compared to 26 females. Maximum age is greatest in the more northern, slower-growing populations.

Most sturgeon seen today come from the commercial fishery, which is governed by minimum total length, minimum weight or net mesh size. As a result, the sturgeon are usually 3–5 feet (91.5–142.5 cm) in total length, and 10–80 pounds in weight. Small numbers of very large sturgeon are still seen each year. A sturgeon weighing 234 pounds was caught in Lake of the Woods in 1965 and one 154 pounds in the Bay of Quinte in October 1969. The latter, 7 feet, 5 inches (226.2 cm) long, probably should have weighed about 200 pounds but was in very poor condition. Harkness and Dymond (1961) listed records for 36 Canadian sturgeon over 100 pounds. Apparently the largest lake sturgeon recorded is one of 310 pounds, 7 feet, 11 inches (241.4 cm) long, caught in Batchewana Bay, Lake Superior, June 29, 1922. A photograph of this fish appeared in the *North Bay Nugget*, June 5, 1936, in an article, by Harkness and Dymond, on the fishes of Lake Nipissing. Because of the difficulty of determining the age of single, very large specimens, ages are not often included. There is, however, a record of 154 years of age for a sturgeon of 208 pounds caught in Lake of the Woods in 1953 (MacKay 1963) — it had, therefore, been born in 1801, 4 years before the battle of Trafalgar!

This species is not often considered a sport fish so is rarely entered in the usual lists of angling records. The list of large sturgeon in Harkness and Dymond (1961) cited many, from areas where there are no commercial fisheries, which may have constituted angled fish. One in particular, weighing 230 pounds and 6 feet, 8 inches (203.3 cm) in length, was caught in the Niagara River on October 28, 1946, by Harding Miller of Fort Erie North. A photograph of this fish appeared in Harkness and Dymond. A caption to an earlier notice, in the *Toronto Daily Star* October 30, 1946, stated that it was entered in the New Jersey Governor's fishing contest, so it may constitute an authentic angler record.

The usual habitat of the lake sturgeon is the highly productive shoal areas of large lakes and large rivers. Most captures are made at 15–30 feet (4.6–9.2 m) but they have been taken, rarely, as deep as 140 feet (42.7 m). They are bottom dwellers, adapted to feeding on the bottom, which consists of mud or gravel and mud. Small sturgeon, 7.7–30.0 inches (19.6–76.2 cm) in length, in Lake Nipigon were most often found on gravelly shoals near the mouths of rivers. It is primarily a freshwater fish but is known from brackish water in the lower St. Lawrence

River, and Hudson and James bays (Harkness and Dymond 1961).

Seasonal movements, other than spawning migrations, are not well known but thought to consist of a move from shallow waters when these warm, into deeper water, a return to the shoals in autumn, and a return movement to moderate depths in winter. In Wisconsin, where there is a winter sport fishery at a maximum of 21 feet (6.4 m), lake sturgeon are active all winter. Spawning migrations out of lakes and up rivers to suitable grounds are often as long as 80 miles but are not known to exceed 250 miles. Strong homing has been described but there are also cases of fish wandering from lake to lake.

Like some very large, marine, filter-feeding fishes, the sturgeons are large fishes that feed almost exclusively on very small organisms they obtain from the bottom by means of the protrusible, tubelike mouth.

Food is searched by constant movement close to the bottom and by the sensory ability of the barbels. Virtually anything edible that will enter the mouth, is sucked up and consumed. Nonedible materials such as mud, sticks, and stones pass out under the opercula or are cast out of the mouth. The food is worked or pulped in the mouth, often partly ejected and sucked in again. Consequently food type ranges widely and composition depends on availability. Harkness (1923) listed the following: crayfish, molluscs, insect larvae (mainly chironomids), nymphs (mainly Ephemeroptera, Trichoptera, and Neuroptera), fish eggs, fishes (rarely), nematodes, leeches, amphipods, decapods, and a few plants. For a complete summary of percent composition, by date, *see* Table 4, p. 35, of that paper and an extensive section in Harkness and Dymond (1961). The only fish identified in the stomach contents by Harkness (1923) was the ninespine stickleback. Sculpins (Cottidae) are another said to occur. Vladykov and Greeley (1963) gave fish as 24% of the stomach contents of lake sturgeon in the St. Lawrence River. They added that the best bait with which to catch lake sturgeon on hooks was American shad, or banded killifish. Algae is apparently eaten at times, and lake sturgeon caught near grain elevators have stomachs filled with wheat, barley, and corn. Feeding ceases during the spawning migration but apparently takes place all winter in some localities.

Lake sturgeon and other bottom feeders such as lake whitefish, consume the same food items but are often not competitive as they feed in different places. The white and longnose suckers are probably its strongest food competitors. The predatory role of the lake sturgeon is known to have been greatly exaggerated in the past. It was assumed from its bottom feeding and the periodic appearance of fish eggs in gut contents that it decimated the eggs of other economically more important species. It is now known that fish eggs form a very small and inadvertent part of its food, probably since it feeds on bottoms not particularly good as spawning locations.

Predators on the lake sturgeon are limited by the scutes of the young and the size of the adults, and Harkness and Dymond (1961) stated that there were no records of the young in the stomachs of other fishes or other animals. Lampreys (*Petromyzon marinus* and *Ichthyomyzon unicuspis*) are known to attack and possibly kill even large sturgeons. The sturgeon of 154 pounds, caught in the Bay of Quinte in October 1969, said above to be in poor condition and low in weight, carried, when captured, 15 large sea lampreys and scars of many other attacks. It was very sluggish and when dressed bled very little. Lamprey attacks may have contributed to its low weight and vulnerability to the very light nets in which it became entangled.

Extensive information on the biology of this species in Quebec was given by Magnin (1963b).

Comparatively few parasites have been recorded from lake sturgeon. Harkness and Dymond (1961) listed the following: Trematoda, 6 species; Acanthocephala, 4 species; Nematoda, 5 species; Cestoda, 1 species; Crustacea, *Argulus canadensis* reported once. The list given by Hoffman (1967) included the following: Trematoda — *Allocreadium* sp., *Crepidostomum lintoni*, *Diclyobothrium armatum*, *D. hamulatum*, *Diplostomulum* sp., *Skrjabinopsolus manteri*; Nematoda —

Cucullanus clitellarius, Rhabdochona cascadilla; Acanthocephala — *Echinorhynchus salmonis, Tanaorhamphus ambiguus*; Crustacea — *Argulus canadensis, A. stizostethi.*

Relation to man No other Canadian freshwater fish has had such a kaleidoscopic relation to man. The lake sturgeon was once looked upon with scorn by fishermen as a worthless nuisance that destroyed gear set for "valuable fish" but has at other times commanded a higher price per pound than any other freshwater commercial fish. Before 1860, this species, taken incidental to catches of other fishes, was killed and dumped back in the lake, piled up on shore to dry and be burned, fed to pigs, or dug into the earth as fertilizer. It was even stacked like cordwood on the wood dock at Amherstburg, Ont., and used to fire the boilers of steamboats plying the Detroit River. They were highly prized as food by some groups of Indians, but only small numbers of sturgeon were sold for food by white fishermen. These went for 10¢ each and were smoked, dried, or brined like corned beef. The eggs were considered fit only as food for hogs or bait for other fishes. Sturgeon were boiled down for the oil which was used in paints. By 1860, North Americans realized the value of the flesh, smoked or fresh, of the eggs for caviar, and of the high quality gelatin isinglass (a word derived from the middle Dutch word *huysenblasse*, meaning sturgeon bladder). This gelatin, extracted from the swim bladder, once sold for $1.00 per pound (10 fish) and was used as a clarifying agent in the making of wine and beer, as a cement for pottery, to size and stiffen textiles, to set jams and jellies, and for waterproofing. The sturgeon skins were even tanned for leather. The fishery for this species then became so intense as to eventually contribute to the reduction of the populations to a level from which they have never recovered. They were taken by every available means from spearing and jigging to set lines of baited or unbaited hooks laid on the bottom, to trapnets, poundnets, and gillnets.

The beginning of commercial preparation of caviar and, later, smoked sturgeon at Sandusky, Ohio, in 1855 and 1860 was the principal reason for the sudden intensification of the fishery for sturgeon in Canada as well as in the United States. In the 10 years between 1885 and 1895, the catch showed the classic course of events often associated with an intense fishery on a slow-growing fish. The Lake Erie catch was initially high, over 5,000,000 pounds, but had dropped by 80% by 1895. In Lake of the Woods the decline in catch was 90% over the 7 years 1893–1900. By 1957 the catch in Lake of the Woods, once known as the largest sturgeon hole in the world, stood at 0.005% of the 1893 maximum. In 1895 that lake alone had contributed 39% of Ontario's total catch of 1.8 million pounds. The Ontario catch has never exceeded 200,000 pounds since 1925. The biology of the fish, the early, intense, indiscriminate fishery, and the effects of dams and pollution on the opportunity and ability of the species to reproduce, have all contributed to the present low levels of populations of lake sturgeons. Most of the sturgeon caught in Canada have been sold to the United States for processing and the sole attempt to produce caviar in Canada was short lived as a result of the declines in stocks.

Although the catches are low, each sturgeon still commands a very high price per pound for flesh and eggs. Since 1959 the yearly catch has fluctuated from a high of 194,638 pounds in 1961 to the level of 85,723 pounds in 1966 with a steady decline over that period. The meat earned a market value of $187,565 or 96.4¢ per pound in 1961 and has risen steadily to the price of $1.22 per pound in 1966. Once used as fertilizer or fed to hogs, the smoked flesh of lake sturgeon is now a gourmet item that few can afford. The price paid for eggs for caviar rose rapidly also. In 1925 it was $1.50 per pound and the highest price paid was in 1952, when it reached $4.33 per pound. Price declined slightly and from 1962 to 1966 it fluctuated between $3.30 and $3.97 per pound. Usually eggs of the lake sturgeon command a higher price than those of other North American sturgeons.

The flesh, especially when smoked, is delicious although rich and oily. It is said that unsmoked sturgeon, not favoured by most people, when properly prepared and properly cooked, is excellent. It is usually made into steaks and fried and is said to taste more like veal than fish. Vladykov (1955b) quoted the Quebec fishermen as saying it has five kinds of meat from different parts of the body.

It is not an important sport fish in Canada, but its size always attracts some attempts to catch it by hook and line. There is an important winter spear fishery by anglers in Michigan and Wisconsin. The regulations governing the commercial and sport fisheries for this species in various places were summarized by Harkness and Dymond (1961).

Nomenclature

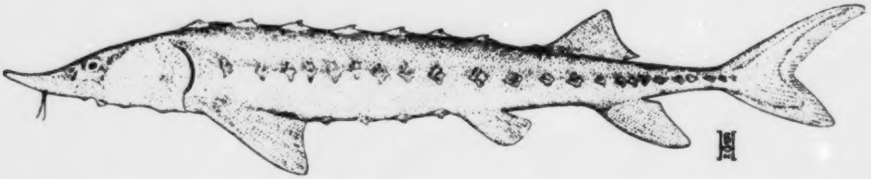
Acipenser fulvescens	— Rafinesque 1817a: 288 (type locality Great Lakes)
Acipenser rubicundus	— LeSueur 1818c: 383
Acipenser Rupertianus Richardson	— Richardson 1836: 311
Acipenser laevis	— Agassiz 1850: 267
Acipenser carbonarius	— Agassiz 1850: 271
Acipenser rhynchaeus	— Agassiz 1850: 276
Acipenser maculosus Lesueur	— Günther 1870: 339
Acipenser athracinus	— Duméril 1870: 126
Acipenser megalaspis	— Duméril 1870: 135
Acipenser lamarii	— Duméril 1870: 139
Acipenser atelaspis	— Duméril 1870: 141
Acipenser rosarium	— Duméril 1870: 152
Acipenser kirtlandi	— Duméril 1870: 161
Acipenser buffalo	— Duméril 1870: 231
Acipenser sturio	— Eigenmann 1895: 107
Acipenser fulvescens obtusirostris	— Roussow 1955: 79
Acipenser fulvescens acutirostris	— Roussow 1955: 79

Etymology *Acipenser* — latin name for a sturgeon; *fulvescens* — dull yellow colour.

Common names Lake sturgeon, freshwater sturgeon, Great Lakes sturgeon, rock sturgeon (usually the long snouted, obviously plated young), stone sturgeon, red sturgeon, ruddy sturgeon, common sturgeon, shell back sturgeon, bony sturgeon, smoothback. French common names: *esturgeon de lac* or *Camus* for adults, and *escargot maillé*, or *charbonnier* for the young.

GREEN STURGEON

Acipenser medirostris Ayres



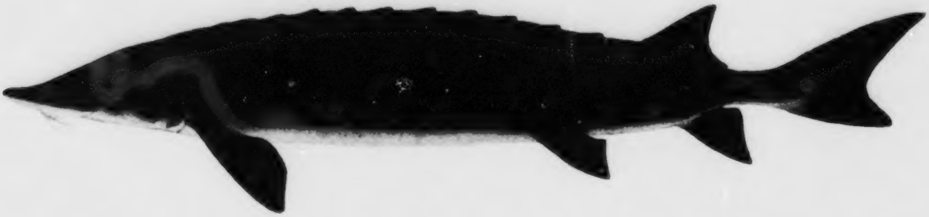
Description This little known, rarely seen species is much smaller than the other Pacific sturgeon, the white sturgeon. Usual length 7 feet (2.13 m). The green sturgeon has a robust rounded body, pentagonal in cross section, greatest depth about 14% of total length, head moderately long, large, broad, without fontanelle, about 23% of total length; eyes small; snout in adults blunt and rounded but sharp, longer than postorbital length, and concave on top in young; mouth ventral, toothless, about 61% of interorbital width; 4 barbels anterior to mouth, nearer to mouth than to tip of snout; gill rakers scarcely longer than broad, 18–20 on first arch. Fins: dorsal 1, far back, over anal, not high nor deeply emarginate, 33–35 rays; caudal markedly heterocercal, upper lobe long, broadly pointed, lower lobe about half as long, difference in total length and fork length is 11% of fork length; caudal peduncle in small animals short, tip of anal not reaching or passing base of lower lobe of caudal; anal longer than dorsal but base ½ base of dorsal fin and origin opposite last ⅓ of dorsal, 22–28 rays; pelvics near anus, pectorals large, rounded; paired fins with heavy ossified first ray; no scales, body covered instead with series of large, hooked plates with interspersed series of smaller stellate plates; tail with scattered plates; dorsal plates 9–11, large, hooked; lateral plates 23–30 not touching; ventral plates 7–10; 1 plate between dorsal fin and caudal fulcrum; 1 plate between anal and caudal fulcrum; 3 plates in single row between anus and anal fin; no lateral line. Skeleton cartilagineous except for membrane bones of skull, lower jaw and pectoral girdle; no vertebral centra, notochord persistent.

Colour Body and head at all sizes definite dark green to olive-green colour; lower edge of head, body, and all ventral surfaces paler to whitish green; in life a marked olive-green longitudinal stripe midventral and lateral between lateral and ventral plates, ending at anus; lateral plates slightly paler than body colour; fins dusky grey to pale, opaque green; viscera pale, without pigment.

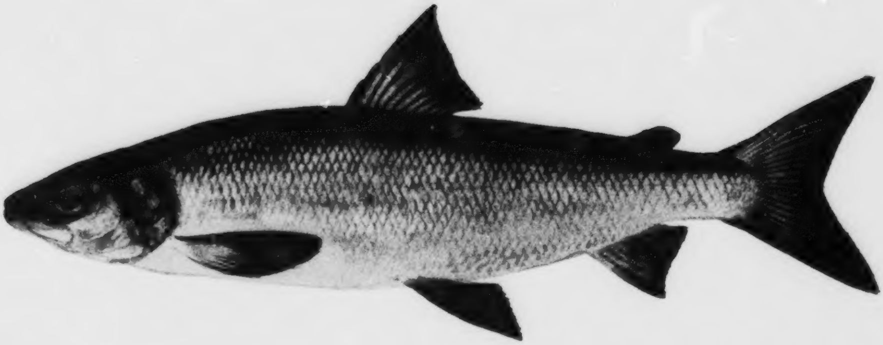
Distribution The North Pacific coasts of Korea, China, northern Japan, the USSR to the Amur River (Berg 1948), and North America from the Gulf of Alaska at least to Petersburg, Alaska (Migdalski 1962) to San Francisco. Usually about the mouths and in the lower reaches of large rivers.

In Canada it is known to occur at Victoria, off Kyuoquot Sound, west coast of Vancouver Island, and in the Fraser and Skeena rivers. In North America it is much less common than the white sturgeon, *A. transmontanus*, and apparently rarely found in fresh water (Carl et al. 1967). In the USSR this sturgeon is said to be rather abundant in the Datta River.

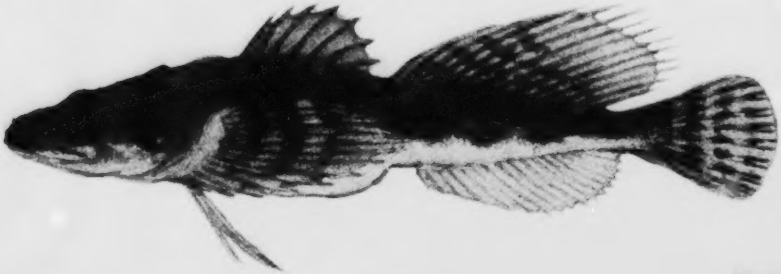
The first Canadian record of this species was a specimen 13.5 inches (343 mm) total length caught in 1908 near Victoria and now in the British Columbia Provincial Museum.



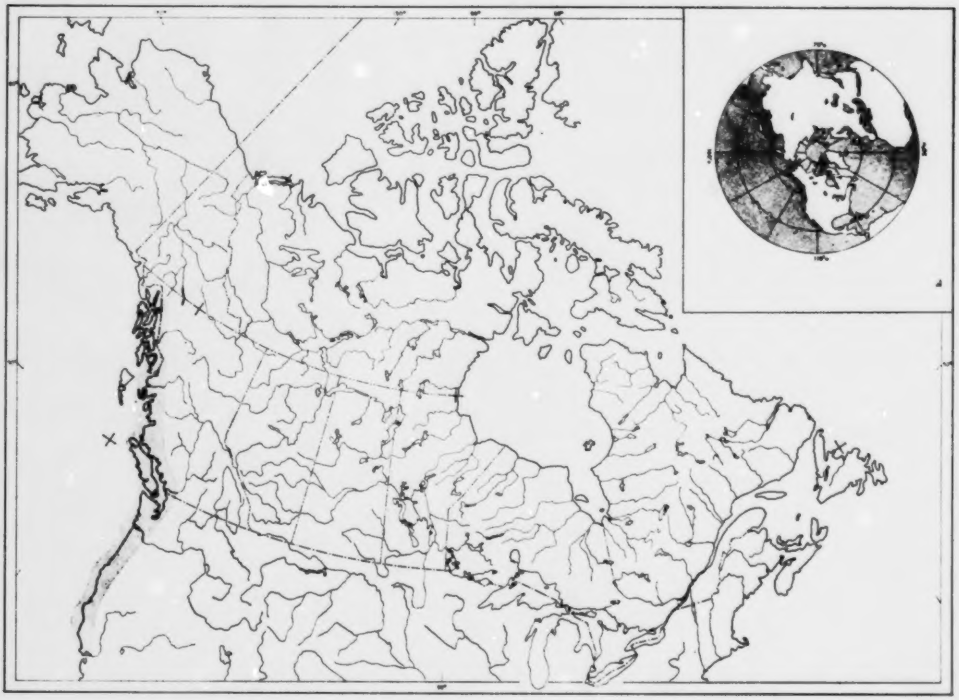
Lake sturgeon



Blackfin cisco



Deepwater sculpin



Biology Virtually nothing is known of the life history of this animal. It is always reported in the literature as rare in fresh water, preferring the mouths of large rivers where it is seen in August and September. Its capture in nets set for salmon (*Oncorhynchus* spp.) in the late summer and early fall in lower Fraser River would indicate that it is anadromous and moves into fresh water through the fall and winter to spawn in the spring. Records from fish tagged in California indicate that at least some individuals travel in the sea distances as great as 660 miles (Chadwick 1959).

Beyond this point various accounts of this species in the literature simply repeat that its life history is assumed to be similar to that of the white sturgeon, said to spawn from the middle of June to the middle of July in the Datta River, USSR.

The largest specimen known from Canadian waters weighed approximately 350 pounds. It is estimated that most green sturgeons seen on the North American coast weigh 50–100 pounds.

Relation to man The flesh of this fish, once thought to be poisonous, has been said to be edible, but dark, with a strong disagreeable taste, and an unpleasant odour. It is considered quite inferior to white sturgeon, bringing only a nominal price and, in the past, the roe was not utilized at all (Jordan and Evermann 1908). Magnin (1959) quoted Russian authors for the fact that it is taken commercially in the Bering Sea. The green sturgeon is taken in nets set for salmon in the Fraser River but there is no statement of its utilization in British Columbia.

Nomenclature

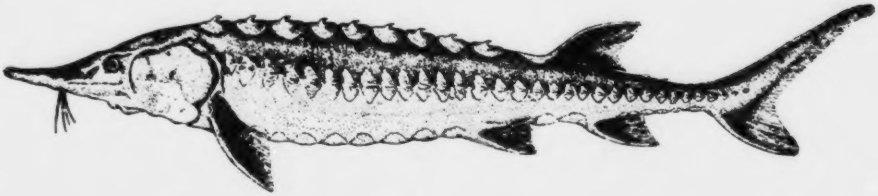
Acipenser medirostris	— Ayres 1854: 15 (type locality San Francisco)
Acipenser acutirostris Ayres	— Jordan, Evermann, and Clark 1930: 34

Etymology *Acipenser* — an old world name for sturgeon; *medirostris* — moderate snout, alluding to a supposed intermediate snout length.

Common names Green sturgeon, Sakhalin sturgeon or *sterlyad* in USSR. French common name: *esturgeon vert.*

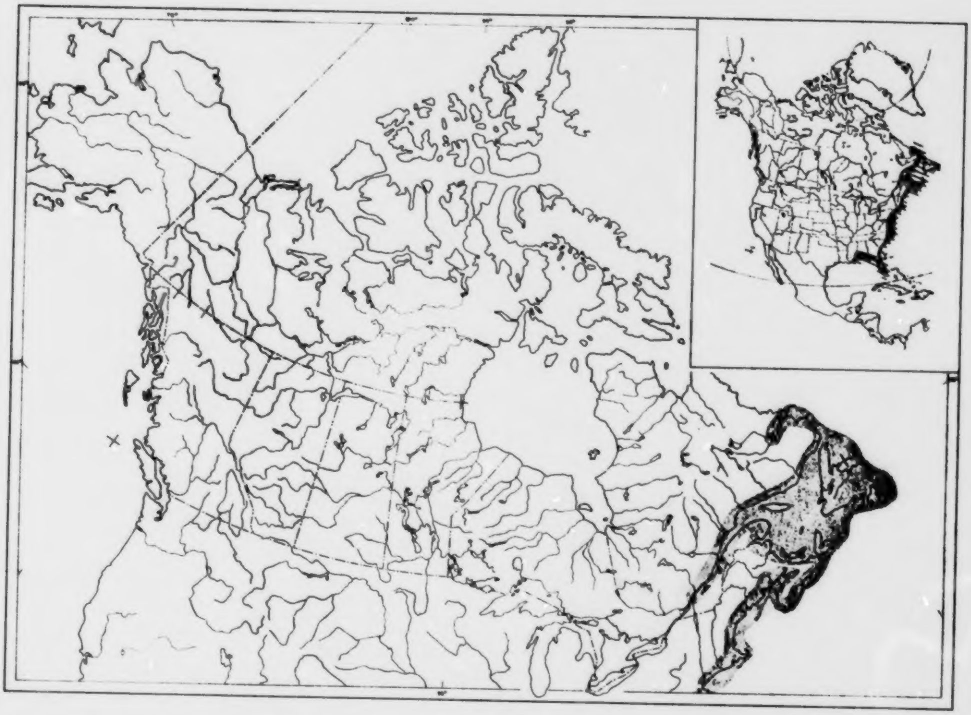
ATLANTIC STURGEON

Acipenser oxyrhynchus Mitchill



Description A large, heavy-bodied fish giving the impression of a pentagon in cross section. Usual length 10 feet (3.05 m). Head elongate as result of longer snout; snout, pointed in young, slightly upturned, flat on bottom, length greater than postorbital distance in fish up to 37 inches (941 mm), but shorter than postorbital distance in larger, older individuals; mouth opening narrow, 55% of interorbital width; no teeth; 4 ventral barbels ahead of mouth midway between tip of snout and mouth; gill rakers long, 15–27 (mean = 21.5). Fins: dorsal 1, far back, opposite anal, high, trailing edge deeply crescentric, 38–46 rays; caudal markedly heterocercal, long, pointed, upper lobe with notch under tip, lower lobe shorter, mean difference between total length and fork length 14% of fork length; anal slightly longer than dorsal, base 66% of base of dorsal, trailing edge little emarginate, 26–28 rays; pelvics abdominal, far back, pectorals large somewhat square at tip, both with heavy, ossified first ray. The body is not covered with scales but with patches of heavy denticles and large, hooked plates, 7–16 dorsal plates, 24–35 lateral plates, 8–12 ventral plates, 6–9 plates behind dorsal in pairs, usually 4 plates behind anal each smaller than anal fulcrum, no lateral line. Skeleton cartilagineous, except for membrane bones of skull, jaws, and pectoral girdle; vertebral centra absent, notochord persistent (Vladykov and Greeley 1963).

Colour Dorsal surface of body and head blue-black, paling on sides, lower edge and lower surface of body and head white, ventral plates white. Spines of dorsal and lateral plates white, contrasting with dark colour of skin; iris of eye golden; leading edge of paired fins and lower lobe of caudal



white, contrasting with dark grey of the rest of the fins, anal fin white, dorsal fin and upper lobe of caudal grey to blue-black with white trailing edge. Viscera and peritoneum white; in preserved specimens unpigmented skin of ventral surface and lower sides of head white to pink, never green. A good colour illustration in Vladykov (1955b).

Systematic notes Although described as a separate species by Mitchill in 1815, by the late 1800's it was being considered as synonymous with, or a variety or subspecies of, *A. sturio*, the European sea sturgeon. This tendency continued into the 1950's in some publications. *See* Magnin (1963a, 1964) for comparisons of, and distinctions between, *A. sturio* and *A. oxyrhynchus*. Vladykov (1955d) described the Gulf of Mexico populations of the Atlantic sturgeon as a subspecies, *A. o. de sotoi*. He strangely attributed to this species old records from Bermuda.

Distribution Limited to the Atlantic coast of North America from Hamilton Inlet, Labrador, or George River, Ungava Bay, to eastern Florida. Early records will include eastern Atlantic as a result of the confusion of this species with *A. sturio*, the common sea sturgeon of Europe. It is replaced in the Gulf of Mexico, according to Vladykov (1955d), by a subspecies, *A. o. de sotoi*, the Gulf of Mexico sturgeon. Old records of *A. oxyrynchus* from Bermuda, Vladykov said, were probably this latter form, which seems odd.

In Canada from George River(?), Ungava Bay, or Hamilton Inlet, Labrador, Blanc Sablon on the Quebec side of the Strait of Belle Isle, throughout the Gulf of St. Lawrence, Gaspé, Bay Chaleur, the St. Lawrence River upstream to Trois-Rivières regularly, and Lac St. Pierre occasionally; rare records off Newfoundland (northwest coast and Hermitage Bay), none from fresh water; better known in Nova Scotia and New Brunswick — Cheticamp, Aspy Bay, Bay of Fundy, Minas Basin, Annapolis River, Avon River, Passamaquoddy Bay, Saint John River, Oromocto and Grand lakes, and Miramichi estuary (Vladykov and Greeley 1963; Leim and Scott 1966).

Biology The Atlantic sturgeon is anadromous, spending much of its life in the sea but returning to fresh water to spawn. The move to fresh water is made actually in advance of spawning time. In the southern part of the range this is apparently in February, becoming later northward where, in the St. Lawrence River, it is late May to early July. In the Delaware River the sturgeon congregated for spawning in the upper reaches in 36–42 feet (10.97–12.80 m) of water over a hard, clay bottom. Spawning occurred at 56°–64° F (13.3°–17.8° C). Virtually nothing is known of the spawning activity of this species, particularly in Canada. Vladykov and Greeley (1963) assumed that it spawned in pools below waterfalls in such tributaries of the St. Lawrence River as Batiscan River and Rivière aux Outardes, and that the spent fish return randomly to sea, the greatest number during September–November. Spawning is probably yearly in some females and ceases only with extreme age or death.

When laid, the eggs are light to dark brown, heavy, and absorb water and quickly become sticky, attach to vegetation and stones as they are randomly distributed over a wide area by the spawning pair. Egg size is 2.5–2.6 mm and calculated egg numbers range from 800 thousand to 2.4 million per female and an estimate of 3,755,745 eggs in a female 8 feet 9 inches (2.65 m) long weighing 352 pounds, with an ovary weighing 91 pounds.

At a water temperature of 64° F (17.8° C) the eggs hatch in about 1 week, the yolk sac lasting a further 6 days. Newly hatched fry are about 11 mm long. Mansueti and Hardy (1967) illustrated and described larval stages in the Chesapeake Bay region.

Little is known of the early growth of the Atlantic sturgeon as the young are rarely seen. Young specimens 2.5–4.3 inches (65–110 mm) total length and 0.7–4.2 grams in weight caught in fresh water of the St. Lawrence River, were considered to be less than a year old. From August to October size of small individuals increased from 5.1 to 7.9 inches (130–201 mm) fork length and weighed from 6.8 to 47.7 grams. The young may spend as long as 3 or 4 years in fresh water before migrating to sea where growth accelerates. Hudson River Atlantic sturgeon 11–34 inches (27.9–86.5 cm) total length were 2–8 winters old as determined from otoliths, but 11- and 12-year-old specimens ranged from 75 to 100 inches (190.7–254 cm) total length. Specimens tagged in the St. Lawrence River over the size range of 27.8–33.3 inches (70.6–84.7 cm) fork length and 4.8–8.8 pounds yielded an estimated annual increment in length of 6.3–14.4% and in weight of 28.8–47.0%. Magnin (1963b) gave the following age–length–weight relation for sturgeon in the St. Lawrence River:

Age	Mean TL		Mean wt
	(inches)	*(cm)*	*(lb)*
1	8.6	22	0.06
2	11.0	28	0.15
3	13.7	35	0.2
4	16.5	42	0.6
5	19.3	49	0.9
6	22.8	58	1.5
7	26.0	66	2.3
8	29.5	75	3.8
9	34.2	87	5.7
10	35.4	90	6.8
11	38.6	98	9.9
12	41.5	105	11.4
13	42.9	109	12.7
14	45.2	115	15.1
15	47.2	120	16.7
20	63.8	162	47.9
46	102.4 (8.5 ft)	260	330.0
60	105.1 (8.8 ft)	267	352.0

This species retains juvenile characteristics up to 4 feet (122 cm) in length.

No female has been reported sexually mature and capable of spawning at a weight less than 150 pounds or an age less than 10 years. Males as small as 69 inches (175.3 cm) total length and a weight of 70 pounds are capable of spawning. In the St. Lawrence River sexual maturity is achieved by males at 22–24 years and by females at 27–28 years. This is at an approximate total length of 65 inches (165 cm) and 74.7 inches (190 cm).

Atlantic sturgeon of 200–300 pounds are not uncommon in the annual catches in Quebec. The largest Atlantic sturgeon known is apparently a 14-foot female, 811 pounds, caught at Middle Island, Maugerville, N.B. about 65 miles off the estuary of the Saint John River, in July 1924. The largest St. Lawrence River specimen was 8 feet 9 inches (266.9 cm) total length and weighed 352 pounds. Magnin (1963b), judged this fish to be 60 years old. The largest individuals are always female.

This species is anadromous so the young are hatched in fresh water and spend up to 4 years there but descend gradually to the sea. Nothing is known of their detailed habitat or activities. They are bottom dwelling fish but are seen at times jumping out of the water. Behaviour in the sea is poorly known; they can adjust without apparent stress to abrupt changes from salt to fresh to salt water. The bulk of the fish produced in any river spend most of their life in the estuary and immediate environs of that river. Tagged individuals have, however, travelled up to 900 miles and this species is taken at sea as far off the continental shelf as Georges and Brown banks.

The young sturgeon in fresh water eat a wide variety of bottom-dwelling plant and animal material, which is taken into the protruded, tubelike suctorial mouth, along with a good deal of mud, while the fish is rooting on the bottom with its snout and sucking in the material. Sludgeworms (*Limnodrilus*), chironomid larvae, mayfly larvae, isopods, amphipods, and small bivalve molluscs have been recorded. In the sea, the larger sturgeon feed on molluscs, polychaete worms, gastropods, shrimps, amphipods, and isopods and small fishes, particularly sand lances, *Ammodytes*. Adults apparently do not eat during migration and spawning and as a result are in poor condition by that time. They do eat in fresh water after spawning is completed and apparently quickly rebuild themselves.

Very little is known of the predators of such large fish. It is known to be attacked and even killed by the sea lamprey. It is possible that its size and protective plates protect it from most predaceous fishes and its habitat and secretiveness from other predators. Since several species of sturgeon inhabit the same rivers, the young compete for food with one another and with other bottom-feeding fishes.

Relation to man This sturgeon provides food of good quality but less so than the lake sturgeon. Actually only large adult Atlantic sturgeon provide tender rich flesh most suitable for smoking, etc., but the bulk of the catch is of half-grown individuals. The price paid in Quebec is 35¢/per pound dressed compared to over $1.00 for the lake sturgeon. and Atlantic sturgeon dress out to only 40–50% of live weight. The flesh was long referred to in New York as "Albany Beef." The eggs are as suitable for caviar as those of the lake sturgeon, and a 352-pound female will yield 91 pounds of eggs. In 1888, a single dealer on the Delaware River shipped 50 tons of eggs for the German market of caviar. The fishery for this sturgeon in Canada is small, 57,000 pounds in 1962 worth $11,000 (Leim and Scott 1966). The catch in Quebec around 1955 was 160,000 pounds with a value of $20,000 (Vladykov 1955b). The catch in the United States today is greater, but only half as large as it was in the 1880's. In colonial New England these sturgeon were an important fish. They were pickled and shipped to England as early as 1628.

Numbers declined seriously in the United States, but the Atlantic sturgeon has been seen more often recently in the Hudson River. It is thought to be as abundant as ever in Quebec waters. Many factors contributed to the declining catch; sale of the young; destruction of young (less than 5 pounds), thought to be another species, since they damaged shad nets; no longer fishing types of gear that take them; and decrease in popularity at prices demanded. In Quebec they are taken in gillnets and in weirs. There is presently no known sport fishery for this species but some are taken incidental to other species. If their haunts were known they could provide sport as the white sturgeon does.

Nomenclature

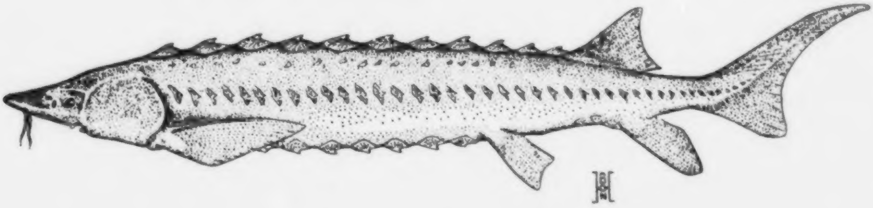
Acipenser oxyrhynchus	— Mitchill 1815a: 462 (type locality New York)
Acipenser sturio (variety *oxyrhynchus*) Linnaeus	— Cox 1896b: 64
Acipenser sturio oxyrhynchus Mitchill	— Halkett 1913: 44
Acipenser sturio L.	— Huntsman 1922: 10
Acipenser oxyrhynchus oxyrhynchus Mitchill	— Vladykov and Greeley 1963: 46

Etymology *Acipenser* — the sturgeon; *oxyrhynchus* — sharp snout.

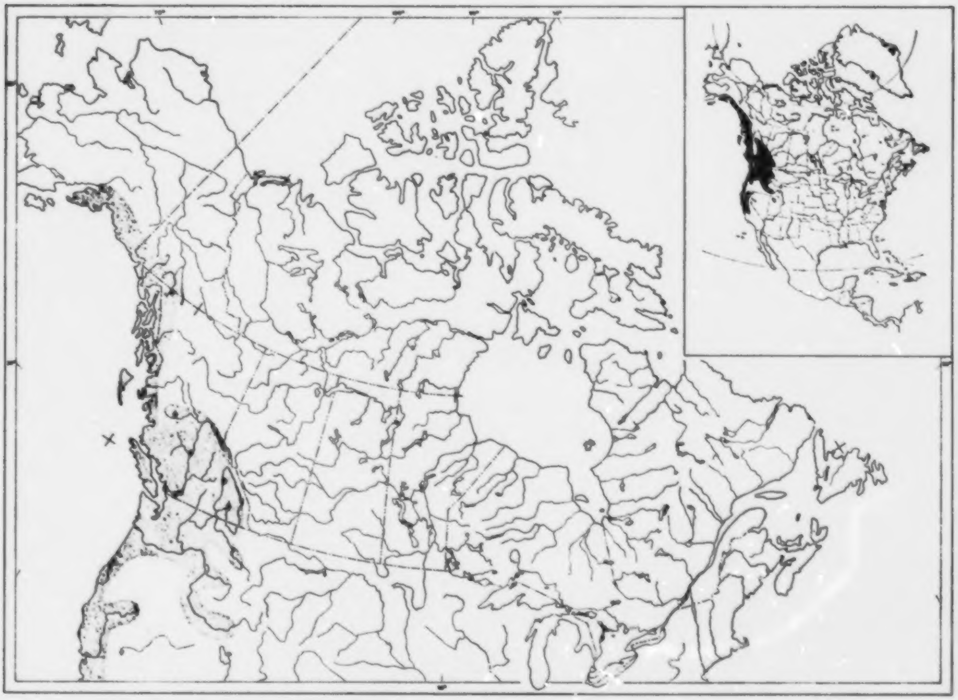
Common names Atlantic sturgeon, sea sturgeon, common sturgeon, the young are called sharpnose sturgeon or pelican. French common names: *esturgeon noir*, and the young, *escargot* or *escaille*.

WHITE STURGEON

Acipenser transmontanus Richardson



Description The largest North American sturgeon and probably the largest fish found in the fresh waters of Canada. Maximum length 20 feet (6.10 m). Body of adult less pentagonal, more rounded than in other species of sturgeons, greatest depth about 14% of total length. Head large, broad, without fontanelle, about 25% of total length, eyes small; snout in adults short, depressed, bluntly rounded, shorter than postorbital length, in young sharper, longer than postorbital length; mouth toothless, wide (74% of interorbital distance), on ventral surface; 4 barbels anterior to mouth, slightly closer to tip of snout than to mouth; gill rakers long, 34–36 on first arch. Fins: dorsal 1, far back, over anal, high, trailing edge deeply notched, 44–48 rays; caudal markedly heterocercal but lower lobe longer, more pointed than in other sturgeons, difference between total length and fork length 16% of fork length; caudal peduncle long, tip of anal reaching lower lobe of caudal; anal with origin under middle of dorsal base, short, little emarginate, 28–30 rays; pelvics near anus; pectorals large, rounded; both paired fins with heavy, ossified first ray. No scales, body covered with patches of very minute dermal denticles and isolated rows of large bony plates, in largest individuals may be inconspicuous, dorsal plates large, pointed, 11–14; lateral plates large, diamond-shaped, 38–48; ventral plates 9–12; no



plates between dorsal and caudal or anal and caudal fins; 8 or 9 small plates, in pairs between anus and anal fulcrum; sometimes secondary rows of smaller plates between usual rows; no lateral line. Skeleton cartilagineous except for membrane bones of skull, jaw, and pectoral girdle, no vertebral centra, notochord persistent.

Colour Dorsal surface to upper edge of lateral plates and head to level of eyes dark to lighter grey, pale olive, or grey-brown, sometimes speckled with white; body below lateral plates, and head below eyes pale grey to white, ventral surface white; all plates light in colour; all fins dusky to opaque grey; viscera pale black and heavily pigmented. Young not distinctly different in colour from adults, simply lighter grey.

Distribution Restricted to the Pacific shores of North America from the Aleutian Islands of Alaska to Monterey, Calif. In Canada it is known to occur in the Fraser River system, including Harrison, Lower Pitt, and Stellako rivers, Fraser and Stuart lakes; Taku River; Kootenay Lake and River; the Columbia River above Revelstoke, B.C.; Duncan Lake, Vancouver Island, and possibly Okanagan Lake. Its coastwise distribution makes its presence in other British Columbia coastal drainages likely. Anadromous in most large rivers but landlocked in the upper Columbia River (mainly from Carl et al. 1967).

The first record of this species in Canada was that of J. K. Lord in 1866 (Clemens and Wilby 1961).

Biology Mature adults of this anadromous sturgeon move into large rivers in the early spring. The movements into and within fresh water are not clear and some adults may enter fresh water in the fall and winter. At times adults move great distances (as far as the Flathead River in Montana) on spawning migrations. The spawning period is usually May and June but could be later for distant migrants. Spawning probably takes place over rocky bottom in swift currents, near rapids or waterfalls, when water temperatures are between 48° and 62° F (8.9° and 16.7° C). Adults survive spawning and return to spawn more than once, but only after increasing intervals of years. In the younger females the interval is 4 years, and 9–11 years in older females. The adults probably migrate downstream in late summer and fall to return to the ocean. Egg number varies with size of female from about 699,000 eggs for a 35-pound female, 7 feet 10 inches (238.8 cm) total length to approximately 3–4 million in the largest spawners (Migdalski 1962). Ovary weight can be as high as 250 pounds. The eggs are brown and sticky and adhere to the bottom when laid. Nothing is apparently known of time to hatching or time to active feeding. Little is available on the growth of fish in the first year or two. Back calculation indicates one-year-old fish varied in length from 4.6 to 14.4 inches (11.7–36.6 cm) fork length (Semakula 1963). In general white sturgeon achieve a length of 20 inches (50.8 cm) total length by age 5, and grow about 2 inches (51 mm) per year to about age 25. Growth rate in length is slower after 35 years in age, and growth is mainly in weight. Growth pattern does not indicate a decrease in rate which might lead to a fixed upper maximum size.

Extensive data on age and growth rates for this species were given by Semakula (1963) and Semakula and Larkin (1968). The following age–weight, age–length data for Fraser River females to 35 years are based on the former publication.

Age (*years*)	Mean FL		Mean wt of sample (*lb*)
	(*inches*)	(*cm*)	
1	8.7	22.1	–
2	12.2	31.0	–
3	14.4	36.6	–
4	16.7	42.4	–
5	19.4	49.3	–
6	21.4	54.4	3.7
7	23.3	59.2	3.5
8	25.8	65.5	8.5
9	29.1	73.9	9.8
10	30.4	77.2	7.7
11	32.3	82.1	14.5
12	34.2	87.0	11.4
13	35.9	91.3	12.6
14	37.4	95.2	13.1
15	39.3	99.2	13.1
20	49.5	128.2	26.9
25	63.2	163.1	45.0
30	72.5	184.4	–
35	80.2	203.7	110.0

Semakula (1963) also stated that a 71-year-old female was 89 inches (226.1 cm) fork length and 173 pounds in weight. An individual 11.5 feet (348 cm) from the Columbia River was estimated to be 82 years old. It is highly possible that the largest specimens are over 100 years of age.

Age at attainment of sexual maturity is, like general growth, extremely variable and different for the sexes. First spawning in Fraser River white sturgeon, estimated from growth pattern, probably takes place between 11 and 22 years of age for males, and in females between 26 and 34 years of age. Spawning is preceded by 2–8 years of slower growth.

White sturgeon most often seen in British Columbia are those taken in the lower Fraser River incidental to salmon fishing. These vary in length from 7 to 89 inches (17.8–226.1 cm) and weigh a maximum of 218 pounds. They are known, however, to have grown much larger in the Fraser in the past and probably do today. The largest white sturgeon ever reported was purported to be over 1800 pounds, taken near Mission, B.C. There is an authentic record of one weighing 1387 pounds from the Fraser opposite New Westminster, reported in the *Daily Columbian*, New Westminster, August 14, 1897.

Apparently the angler record to date is a 394-pound fish taken below Swan Falls on the Snake River, Idaho.

This anadromous sturgeon spends most of its time in the sea. It is thought to stay close to shore in shallow water where it has been seen leaping, but is known to depths of 100 feet. It has been taken in water temperatures ranging from 32° to 74° F (0.0°–23.3° C) in salt, brackish, and fresh water. Movements in the sea are not well known, thought to be usually only local, but tagged fish have been known to move as much as 660 miles (Chadwick 1959). In fresh water there are unaccountable movements of small sturgeon upstream during the fall and early winter with a corresponding move downstream during late winter and early spring. Other vague seasonal movements, such as from deeper water in winter to shallower water in warm weather, and toward the ocean in summer months and fresh water in winter months, have been described (Migdalski 1962).

This species, like the other sturgeons, is mainly a bottom feeder, for which its ventral barbels, and ventral, protrusible, sucker mouth admirably adapt it.

The food of smaller sturgeon is predominantly chironomids, which occurred in 35.2% of the stomach of sturgeon of all sizes. Lesser amounts of mysids, *Daphnia*, *Chaoborus* larvae, molluscs, immature mayfly, caddisfly and stonefly, and a few copepods made up the rest of the food.

For individuals larger than 19 inches (483 mm) in length, fish become the principal food with crayfish *Pacifastacus* spp. second. Fish occurred in 48.6% of the stomachs that contained food but were more frequent in the larger sturgeon. Chironomids are also an important part of the diet of adults. In May, migrating eulachons were the most prevalent food items. Many of these, and lampreys, may have died after spawning and been sucked up off the bottom. However, other fishes such as: sculpins *Cottus* spp., threespine stickleback, and four sturgeons (*Acipenser transmontanus?*) found in a single stomach, must have been caught alive. The white sturgeon is apparently much more predaceous or piscivorous than any other North American sturgeon (Semakula 1963; Semakula and Larkin 1968). Fishes as well as a wide variety of invertebrates probably make up the diet of this species when in the sea. White sturgeon either spend considerably more time in fresh water, or feeding does not stop until very shortly before spawning occurs.

There are no published accounts of predators of either young or adult sturgeon other than reports of attacks by the Pacific lamprey, *Entosphenus tridentatus*. Its size and protective plates may account for this. White sturgeon probably compete for food in fresh waters with the other Pacific sturgeons, the green sturgeon, *Acipenser medirostris*, as well as other bottom-feeding fishes.

The most serious limitation to this anadromous species may be the physical and ecological barriers created by dams and their impoundments.

Parasites listed for this species by Hoffman (1967) were as follows: Trematoda — *Nitzschia quadritestes*; Nematoda — *Cystoopsis acipenseri*.

Relation to man The flesh of this sturgeon is highly acceptable as food and the eggs, sometimes as many as 200 pounds in a single female, are readily prepared and marketed as caviar. The bulk of the Canadian commercial catch of this species comes from the Fraser River where it is taken in nets set for salmon (*Oncorhynchus* spp.). It has also been taken in otter trawls in the Strait of Georgia, purse seines on the west coast of Vancouver Island, and in salmon traps near Sooke (Clemens and Wilby 1961). Until 1928 it was legal to take it with set lines in the rivers. Over the years 1880–1963, the catch has been from 80,000 pounds to a low of 9800 pounds in 1942, to the greatest catch recorded, in 1897, of 1,137,696 pounds. Catches in recent years have fluctuated between 25,000 and 40,000 pounds. Prior to 1880 there was only a small subsistence fishery that yielded food to the Indians and isinglass from the swim bladder, which was sold to the Hudson's Bay Company. After the salmon fishery began, local markets for caviar and sturgeon flesh increased. By 1894 exports to eastern markets were being made. The peak catch of 1897 ensued and this was followed by a sharp decline (93.3% reduction in catch 1897–1905) to practically commercial extinction and reduction in licenses. Catch, size, and gear regulations were imposed, the catch recovered somewhat, but then declined in spite of the regulations. Since 1918 commercial catch has ranged from 10,000 to 50,000 pounds annually.

A diffuse sport fishery in the Fraser system might take an additional 20,000–30,000 pounds annually.

Nomenclature

Acipenser transmontanus — Richardson 1836: 278 (type locality Fort Vancouver, Columbia River)
Acipenser aleutensis — Heckel and Fitzinger 1836: no page number

Etymology *Acipenser* — old world name for sturgeon; *transmontanus* — beyond the mountains. Richardson who had come from the east was alluding to its Pacific coast distribution.

Common names White sturgeon, Pacific sturgeon, Oregon sturgeon, Columbia sturgeon, Sacramento sturgeon. French common name: *esturgeon blanc*.

Suggested Reading – Acipenseridae

Dees, L. T. 1961. Sturgeons. U.S. Fish Wildl. Serv. Fish. Leafl. 526: 8 p.

Greeley, J. R. 1937. Fishes of the area with annotated list, p. 45–103. *In* A biological survey of the lower Hudson watershed. Suppl. 26th Ann. Rep. N.Y. Conserv. Dep. 1936, 11: 373 p.

Harkness, W. J. K. 1923. The rate of growth and the food of the lake sturgeon (*Acipenser rubicundus* LeSueur). Univ. Toronto Stud., Biol. Ser. 18, Publ. Ont. Fish. Res. Lab. 18: 15–42.

Harkness, W. J. K., and J. R. Dymond. 1961. The lake sturgeon. The history of its fishery and problems of conservation. Ont. Dep. Lands Forests, Fish Wildl. Br. 121 p.

Kirsch, P. H., and M. W. Fordice. 1889. A review of the American species of sturgeons (Acipenseridae). Proc. Acad. Natur. Sci. Philadelphia 2: 245–257.

Magnin, É. 1959. Répartition actuelle des acipenserides. Rev. Trav. Inst. Pêches Mar. 23: 277–285.

MS 1963. Recherches sur la systématique et la biologie des Acipenserides *Acipenser sturio* L., *Acipenser oxyrhynchus* Mitchill, *Acipenser fulvescens* Raf. Thèse de Docteur ès Sciences Naturelles, Univ. de Paris. Imprimerie Nationale, Sér. A, no. 3964, Paris. 242 p.

1963. Notes sur la répartition, la biologie et particulièrement la croissance de l'*Acipenser brevirostris* LeSueur 1817. Natur. Can. 90: 87–96.

Magnin, É., et G. Beaulieu. 1963. Étude morphométrique comparée de l'*Acipenser oxyrhynchus* Mitchill du Saint-Laurent et de l'*Acipenser sturio* Linné de la Gironde. Natur. Can. 90: 5–38.

Roussow, G. 1957. Some considerations concerning sturgeon spawning periodicity. J. Fish. Res. Bd. Canada 14: 553–572.

Semakula, S. N. MS 1963. The age and growth of the white sturgeon (*Acipenser transmontanus* Richardson) of the Fraser River, British Columbia, Canada. M.Sc. Thesis. Dep. Zool., Univ. British Columbia, Vancouver, B.C. 115 p.

Vladykov, V. D. 1955a. Fishes of Quebec. Sturgeons. Dep. Fish. Que. Album 5: 11.

1955b. A comparison of Atlantic sea sturgeon with a new subspecies from the Gulf of Mexico (*Acipenser oxyrhynchus de sotoi*). J. Fish. Res. Bd. Canada 12: 754–761.

Vladykov, V. D., and G. Beaulieu. 1946. Études sur l'esturgeon (*Acipenser*) de la Province de Québec. Natur. Can. 73: 143–204.

Vladykov, V. D., and J. R. Greeley. 1963. Order Acipenseroidei, p. 24–60. *In* Fishes of the western North Atlantic. Mem. Sears Found. Mar. Res. 1(3): 630 p.

THE GARS — Order Lepisosteiformes

Gars are long, slender, cylindrical, predaceous fishes; with typical rayed fins; and a completely ossified skeleton. The head consists of many, heavy, small bones, but the opisthotic and supraoccipital are missing. The characteristic long, slender snout, which represents a lengthening of the ethmoid, is well armed with needle-like teeth. The lower jaw articulates with the skull in front of the eye. The body is completely covered in an armour of two-layered, ganoid scales most of which are joined by a peg and groove articulation. The pelvic fins are abdominal. The dorsal and anal fins are far back, opposite, and their rays bear a 1:1 relation with the supporting radials. All fins are without spine, but the anterior margins bear rows of fulcra. The tail is abbreviate heterocercal — heterocercal in internal structure, but externally superficially symmetrical. The vertebrae are ossified and of a unique opisthocoelous nature (anterior face convex, posterior face concave). The gars are physostomous, the swim bladder connected to the oesophagus, and the nasal openings connected to the pharynx. The swim bladder is cellular and highly vascularized. Gars are thus able to come to the surface and breathe atmospheric oxygen.

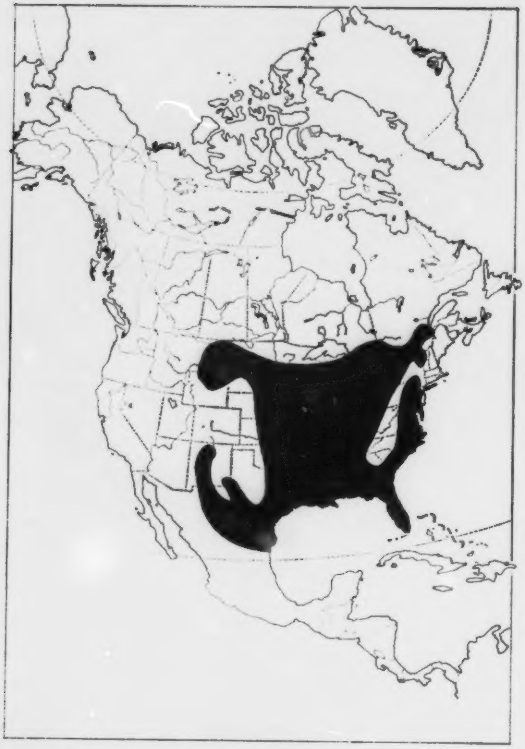
Once associated with Amiidae and Polypteridae they are now considered the sole living representative of a separate order known as fossils from the Jurassic.

GAR FAMILY — Lepisosteidae

The basic characters of this, the only family in the order, are as given for the order. They are long, cylindrical, predatory fishes with long, narrow, well-toothed snouts. The gars are primitive fishes with body covering made up of heavy, ganoid scales.

Primarily fishes of tropical and temperate fresh waters, some frequent brackish water, and to a lesser degree salt water. The single genus *Lepisosteus* contains 7 species sometimes organized in the subgenera *Lepisosteus* and *Atractosteus.* Gars are usually considered restricted to the New World but a species, *L. sinensis*, supposedly occurs in China. In the New World gars occur from Quebec, west to the Mississippi, and south to Costa Rica and Cuba.

Fossil evidence of this group dates from the Upper Cretaceous of Europe, the Eocene in India, and the Middle Eocene of North America.



World Distribution of the Gars, excluding China

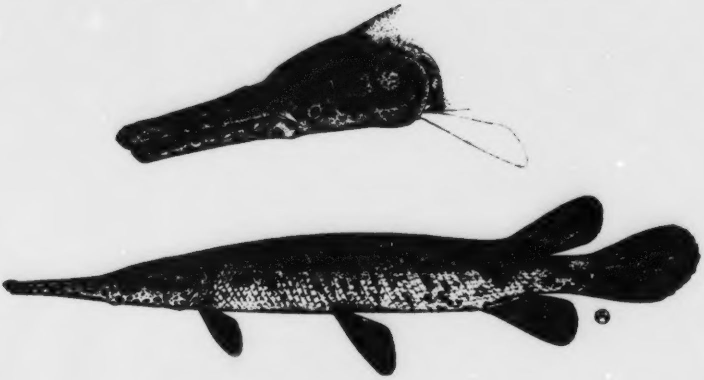
KEY TO SPECIES

1 Snout long and narrow, least snout width into snout length 14–18 times; caudal peduncle shallow and long, least depth into length 2.3–3.4 times; lateral line scales 61–65; spots on body apparent only from pelvic fin to caudal peduncle, spots on dorsal, anal, and caudal fins. .... LONGNOSE GAR, *Lepisosteus osseus* (p. 105)

Snout shorter and broader, least snout width into snout length 6–8 times; caudal peduncle deeper and shorter, depth into length 2–2.3 times; lateral line scales 53–57; body, head, and all fins conspicuously spotted. .... SPOTTED GAR, *Lepisosteus oculatus* (p. 103)

SPOTTED GAR

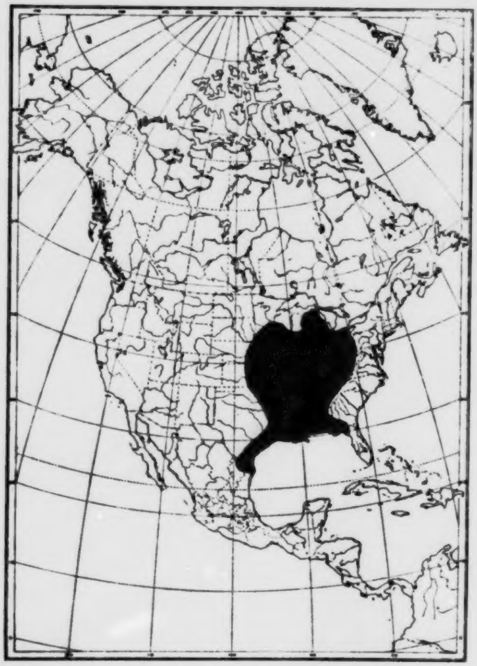
Lepisosteus oculatus (Winchell)



Description Body long, oval in cross section, greatest body depth near anal fin, 7.9–10.9% of total length, usually 16–24 inches (406–610 mm) in total length; head long, 29.0–39.3% of total length, very bony, with pronounced depression in front of eyes; eyes in centre of head, moderately large, 8.2–11.0% of head length; interorbital distance, 11.8–20.9% of head length; snout long, 43.6–82.8% of head length, proportion variable with size, not so long as that of the much more common longnose gar, *L. osseus*, nostrils at tip; snout narrow (but broader than *L. osseus*), least width 9.9–16.0% of snout length, but wider than longnose gar; mouth with large number of sharp, needle-like teeth; teeth in row on palatines in fish longer than 12 inches (305 mm) small, but enlarged in smaller individuals; gill rakers 15–24 (mean = 19.3). Fins: dorsal and anal near caudal, opposite one another; base of dorsal shorter than that of anal, length 13.7–17.6% of total length, 7 or 8 rays; length of anal 12.0–18.7% of total length, rounded at tip, 8 or 9 rays; caudal peduncle shorter, deeper than longnose gar, depth 43.4–49.4% of length; caudal rounded but abbreviate heterocercal. There is in all gars a unique development sequence in the caudal fin at lengths less than 10 inches (254 mm). There is in this species and *L. osseus* a prominent, very motile, rayless, expanded filament on the dorsal and ventral surfaces of the notochord; the small, developing, rayed anal fin projects downward at 45°. Gradually the filament disappears and the anal assumes the shape and proportions of the adult. The pelvic fins are at the midpoint of body, wide, rounded at tip, 6 rays; pectorals very broad, distinctly rounded, 9–13 rays. Scales very heavy, rhomboid, articulated not overlapping, 53–57 in lateral series; lateral line apparent, complete; vertebrae characteristically convex in front, concave behind.

Colour Young brightly coloured; median, dorsal stripe broad and dark brown; dark, straight, lateral band with narrow reddish stripe above; ventral surface chocolate colour. At approximately 4–6 inches (102–152 mm) in length the spotted pattern characteristic of the adult begins to develop. Adults darker, less shiny than more common longnose gar, velvety brown; with darker brown spots, some as large as the eye, on snout, head, sides of the body, and fins.

Systematic notes The two short nosed gars in the north of North America were long confused and referred to as *L. platostomus*. When it was realized that two distinct forms were involved, Cope's 1865 name *productus* was applied to the spotted gar. Later, it was realized *L. oculatus* had priority. *Lepisosteus platostomus*, the shortnose gar, does not occur in Canada and apparently occurs in the Great Lakes drainage only in Wisconsin (Priegel 1963a).



Distribution The spotted gar occurs to only a limited extent in the Great Lakes basin but generally in the Mississippi River basin. It occurs from Lake Erie, Lake Huron (Saginaw Bay and south), Lake Michigan, the Ohio River possibly as high as Chautauqua Lake, N.Y., south to Alabama and western Florida, in the west from southern Minnesota, eastern Nebraska to eastern Texas as far as the Rio Grande River. More confined to fresh water than *L. osseus* but found in brackish water in the south (Suttkus 1963).

In Canada, it is limited to central and western Lake Erie, the Detroit River, and Lake St. Clair. It is not common and is rarely seen.

Biology The spotted gar is so rarely encountered in Canada that there are only eight specimens for study in the collection of the Royal Ontario Museum. There is no information on the biology of this species in the north and what little is known on populations in the south was summarized and published by Carlander (1969). It is stated in many publications that the biology of this species is very similar to that of *L. osseus*, but no detailed discussion seems to be available.

This gar spawns in the spring, in shallow, warm water where aquatic vegetation is abundant. Individuals 20.5–22.6 inches (522–575 mm) were said to be spawners (Suttkus 1963).

The food is almost exclusively fish, and Scott (1967) listed yellow perch, *Perca flavescens*, and minnows (Cyprinidae) as forming a large part of the diet. Feeding is most active in the morning (Carlander 1969).

Scott (1967) indicated 24 inches (610 mm) as the estimated average length in Ontario. Suttkus (1963) listed fish as large as a female of 29.8 inches (757 mm) from brackish Lake Pontchartrain, Louisiana. Migdalski (1962) recorded a spotted gar 44 inches (111.8 cm) long and 6 pounds in weight from Ohio. Maximum weight given by Carlander (1969) was 6 pounds, and growth rate of young was 1.4–2.1 mm and 0.7–1.3 grams per day in Oklahoma. Females are larger than males at the same age and probably live longer, as do females of *L. osseus*.

Relation to man The spotted gar is universally listed as an obnoxious fish because of its voracious and piscivorous feeding habits. Its true effect on fishes considered more valuable by man, and its possible benefit in management by controlling the numbers of smaller species, is largely unknown. The flesh is edible but not favoured. The eggs are probably poisonous as are those of the other gars.

Gars can be taken by hook and line, snare, or spear, but are so rare that none have been reported captured by anglers in Canada. They are not protected by commercial or sport fishery regulations.

Nomenclature

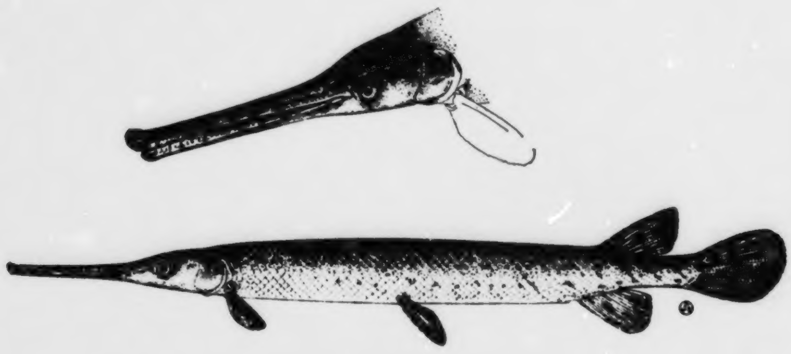
Lepidosteus (Cylindrosteus) oculatus — Winchell 1864: 183 (type locality Huron River, Mich., type specimen UMMZ 55062)
Lepisosteus platostomus — Nash 1908: 16
Lepidosteus platostomus Rafinesque — Halkett 1913: 45
Lepisosteus productus — Hubbs and Lagler 1941: 26

Etymology *Lepisosteus* — scale bone; *oculatus* — eyelike markings, referring to size, shape, and colour of spots.

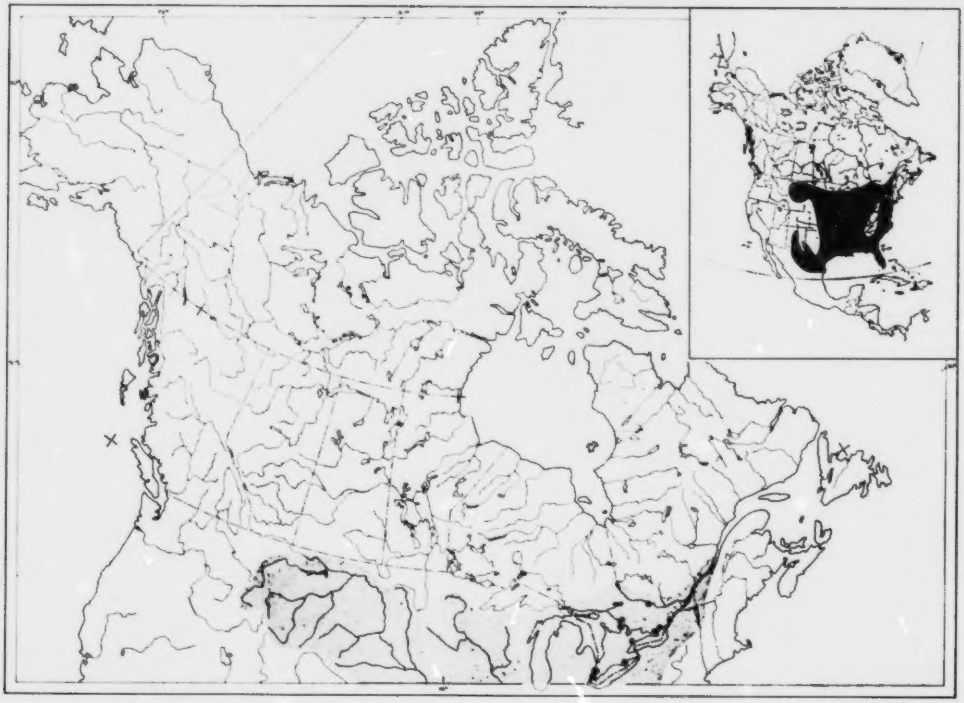
Common names Spotted gar, shortnose gar, short-nosed gar, billfish. French common name: *lépisosté tacheté.*

LONGNOSE GAR

Lepisosteus osseus (Linnaeus)



Description Very long, cylindrical, slender, rodlike body; greatest body depth 5.5–7.4% of total length. They grow to 6 feet (183 cm) but those usually seen in Ontario are 2–3 feet (610–915 mm) in length. Head with characteristic, very long, narrow, bluntly pointed snout, with nostrils at tip, lower jaw conspicuously overhung by snout, head length 27.0–30.3% of total length, snout length 69.2–75.4% of head length, least snout width 5.8–6.2% of snout length; eye moderately large, interorbital width 10.5–13.7% of head length; gill rakers 24–28; teeth very abundant in whole of snout, villiform and sharp; caudal peduncle moderately long and narrow, least depth 29.1–36.5% of



length. Fins: single dorsal far back, nearly rectangular, high, with short base, above anal; dorsal base 83.5–97.6% of anal base, dorsal rays 7 or 8, anal rays 7–9; caudal rounded but abbreviate heterocercal, 11–14 heavy rays. Pelvic fins midabdominal, tip bluntly pointed, with 6 rays; pectoral fins low, only moderately wide, tip pointed, rays 10–13. Scales moderately large, thick, bony (ganoid scales), do not overlap but with peg and socket connection, 61–65 in lateral line series; thin, bony scutes on leading edges of unpaired fins and on both edges of caudal fin. Lateral line present and complete. The vertebrae of the gars are uniquely shaped, convex in front, concave behind.

Colour Adults usually soft olive-brown to dark green on the back and upper sides, lateral surfaces pale green or silver with white below. Median fins bright yellow to pale brown with large dark green, brown, or black spots; body with scattered spots of same size, mostly from pelvic fins back; paired fins dusky, usually without spots. Young are distinctively marked, velvety brown, rusty brown or velvety black contrasting sharply with cream to white. A broad, wavy, brown or black lateral band from snout to base of caudal fin, similar mid-dorsal stripe; ventral surface rich brown bordered by areas of cream to white. Spots on fins larger, more blotched, or in the form of bars (from Suttkus 1963). Good colour illustrations were included by Moore (1930).

Distribution The longnose gar is restricted to fresh and brackish waters of North America. It occurs from Quebec to Montana, south, in the east, through Lake Champlain to New Jersey, down the coastal plain to Florida, and in the west from Montana, northern Wyoming, central South Dakota, south to eastern Texas, northern Mexico and the Rio Grande River in New Mexico.

In Canada it occurs in Quebec as far down the St. Lawrence River as Ste. Anne de la Pocatière, 75 miles below Quebec City, in the eastern townships, and in Ontario south of a line from Lake Temiskaming to Sault Ste. Marie, including the lower Great Lakes. There is a single record north of this line, a specimen 26.8 inches (682 mm) in total length, from Nipigon Bay, Lake Superior, caught in June, 1961. This is the only record from Lake Superior in Canada. It is almost equally uncommon on the south shore of Lake Superior.

Although typically a freshwater fish it enters brackish water in its coastal distribution, particularly in the south. The salinity at the Ste. Anne de la Pocatière site was 13–20‰ on the surface to 25‰ on the bottom (Jean 1946).

Biology The longnose gar was said by Bensley (1915) to spawn in Georgian Bay, Lake Huron, in the middle of June. He said also it builds crude nests in 2 feet (610 mm) of water, on a bottom covered with short stems of aquatic plants. Beyond this, a few scattered notes on food and habits, comments on its destructive nature toward game and forage fish, and the numbers taken in control projects, constitute the Canadian literature on this species. Presumably, since it is of no economic importance it has never been deemed worthy of study in Canada.

Spawning takes place in the warm water of the shallows of lakes or large streams, over vegetation, in late spring or early summer depending on locality. There is evidence that some longnose gars make upstream spawning migrations. Netsch and Witt (1962) suggested gars move upstream to spawn coincident with the occurrence of spring freshets. Adults appear in large numbers over known weedy, spawning beds, and it is thought group spawning takes place; no nest is built, and the adhesive eggs, scattered randomly, become attached to vegetation. Eggs are large, 2.1–3.2 mm in diameter and dark green in colour. Number of eggs per female varied, in Missouri, from 4273 to 59,422 (Netsch and Witt 1962) with an average number of 27,830 for females 30.2–53.9 inches (76.7–137.0 cm) in length, or 3002 eggs/pound of body weight. Egg number as high as 77,156 has been recorded for a Florida longnose gar 56 inches (142.3 cm) long and 32 pounds in weight (Holloway 1954). In the warm, shallow waters of the spawning sites of this species eggs hatch quickly, 6–8 days in Wisconsin (Cahn 1927). *See* Fish (1932) for details and drawings of early development of young. *See also* Mansueti and Hardy (1967) for illustrations and description of larval stages in Chesapeake Bay region.

Young gar have an adhesive pad on the tip of the snout by which they adhere to vegetation above the bottom. They grow very rapidly, possibly 6 times as fast as the young of other North American freshwater fishes. In an experimental situation (mean water temperature 79.5° F or 26.4° C) they grew from 5.3 inches (135.7 mm) to 11.4 inches (289.6 mm) in 52 days with daily increments ranging from 2.7 to 3.9 mm. This species is characterized by unusual age and growth characteristics, large growth differential, and striking difference in longevity between sexes. Females grow faster, become larger, and live longer. Sex ratios in early life are as high as 262 males per 100 females but after age 10 these are as low as 8 males per 100 females.

Ages have been determined in longnose gar by means of otoliths, ceratohyal bones, and branchiostegal rays. Netsch and Witt (1962) used rings on the surface of cleaned branchiostegal rays and demonstrated annuli to corroborate this method. From this they also calculated a linear regression, $L = 131 + 3.8490\ R$ where L = total length in mm and R = length of branchiostegal in mm × 6.25, for back calculation of size at various ages.

At the end of the first year, females were 2.5 inches (64 mm) longer than males and this disparity increased to 7 inches (178 mm) at age 11, at which age males suffered almost complete mortality.

Mean age–length relation at time of capture is given in the following table for males and females in Missouri from 1 to 22 years of age (Netsch and Witt 1962).

Age	TL (male)		TL (female)	
	(inches)	*(cm)*	*(inches)*	*(cm)*
1	17.4	44.2	20.2	51.3
2	23.9	60.7	–	–
3	25.4	64.5	24.8	63.0
4	29.5	74.9	29.3	74.4
5	28.5	72.4	27.0	68.6
6	30.0	76.2	31.8	80.8
7	30.4	77.2	35.4	90.0
8	33.2	84.3	34.6	88.0
9	29.6	75.2	35.0	89.0
10	29.9	75.9	30.8	78.2
11	31.7	80.6	39.6	100.6
12	–	–	41.5	105.4
13	38.4	97.5	37.2	94.5
14	–	–	44.5	113.0
15	–	–	46.5	118.1
16	–	–	45.4	115.3
17	40.5	102.9	45.0	114.3
18	–	–	45.9	116.6
19	–	–	44.7	113.5
20	–	–	47.2	119.9
21	–	–	–	–
22	–	–	49.5	125.7

Netsch and Witt illustrated a curvilinear length–weight relation for specimens 3.7–53.9 inches (9.4–136.9 cm) in total length and 0.01–19.01 pounds in weight. This relation was $\log W = -7.0670 + 3.5075 \log L$, where W = weight in g and L = total length in mm. They also documented losses in weight, of up to 50%, in both sexes after spawning.

Maximum age of the Missouri specimens was 17 years in males and 22 years in females. Netsch and Witt (1962) recorded only two males beyond 11 years of age. Maximum size for this species is usually given as 5 feet (152.5 cm), but Walden (1964) gave the angler record as a gar 6 feet ¼ inch (183.4 cm) long, weighing 50 pounds taken in the Trinity River, Texas, July 30, 1954.

The usual habitat of this species is the quiet, weedy shallows of warm lakes or fairly large rivers where, in summer, the adults are often seen in groups, motionless at or near the surface. Apparently nothing is known of their habitat or activities in the north in ice-covered waters. They can withstand the warmest waters of the north and their ability to respire by gulping air at the surface enables them to live successfully in stagnant ponds, sloughs, and canals in the south. On the coasts they are often found in brackish water and, less often, in supposedly fully salt water. Short spawning migrations up streams have been described. Gars are apparently most active at night. The general conviction that the longnose gar is highly destructive of more valued fishes is doubtless the reason the bulk of the literature deals with food analysis.

This gar waits quietly in the cover of vegetation or debris, darts out at a nearby prey and, with a sideways thrust of its long beak, impales it crosswise in its needle sharp teeth. After a short time the food is moved back by successive movements and is eventually swallowed. The food of very small longnose gar consists of invertebrates, particularly larvae of aquatic insects. The fish quickly become piscivorous and numbers of minute minnows were found in a gar as small as 2 inches (51 mm) long. From that point on, fish form 59–88% of the diet. Several sunfishes and basses (Centrarchidae), suckers (Catostomidae), perches and darters (Percidae), catfishes (Ictaluridae), silversides *Labidesthes sicculus*, pikes (Esocidae), and various minnows (Cyprinidae) are most often represented in the list of fishes eaten in various places. Virtually all fishes that share its warmwater habitat are food for this voracious feeder. Other items include frogs, several species of crayfish (*Cambarus*), a short tailed shrew (*Blarina brevicauda*) in Indiana, and blue crab (*Callinectes sapidus*) in Louisiana. This species consumes large numbers of fishes and has a high food conversion efficiency. The rate of food intake with increase in length has been given as varying from 10.1% body weight/day, to 11.3% to 8%. Unlike many of the other gars, which eat dead as well as living material, the longnose gar is not considered a scavenger.

Its armour of ganoid scales and its secretive nature seem to protect it from predators, and records of its presence in the food of other fishes is limited to 1% of stomach contents (MacKay 1963). Although many other predatory, warmwater fishes, especially pikes, prey on the same species, the gars are able to succeed in waters where other predators cannot. Even in Canada this gar could, in summer, prey on fishes in hot shallows into which other predators may not be able to penetrate.

Parasites of the longnose gar (12) were listed in detail by Hoffman (1967) and included Trematoda (3), Cestoda (4), Nematoda (1), Acanthocephala (1), and Crustacea (3).

Relation to man Published comments on the longnose gar invariably utilize the words noxious, destructive, valueless, and nuisance. Large gars are destructive to fixed gear set for other fishes. Their flesh is not particularly attractive and, although used to a slight extent as food by man in the south, is scarcely used in the north. The eggs of gars are poisonous to man, other mammals, and birds. Consuming them causes severe illness in larger animals and, in some cases, death in smaller ones. Few animals will eat them, however. They are apparently not toxic to fishes since they have been recorded from the stomach contents of several fishes. Any gars marketed by Ontario fishermen were grouped as mixed scrap and animal food in the 1966 statistics of annual landings. This catch in 1966 (mostly alewife) was 1.5 million pounds, worth 11.6 million dollars. Up to 1967, landings of gar were reported as a unit with alewife, shad, and dogfish. In most areas they are killed and discarded. This species as well as the shortnose gar, *L. platostomus*, are, in the Mississippi, the host of the glochidia of the economically important shell mussel, the yellow sand-shell, *Lampsilis anodontoides*. Gars have been artificially infected and released in order to propagate this mussel.

The consequence of their feeding on species of fishes considered by man as more important has never been settled. In a study (Lagler and Hubbs 1940) that separated the fishes found in the stomachs of longnose gars into "game and pan fish" (basses, sunfishes, perch, and bullheads) and "other fishes" (mostly minnows, darters, and silversides), the relative percentages by volume were 59.9% and 36.5%. There is, however, no statement of the relative abundance of these species in the habitat. It would seem probable that the longnose gar is a voracious species, it may be a simple opportunist, and its effect on desirable species overemphasized. Its activity as means of advantageous control of numbers of small fishes, and the beneficial effects that might follow its removal, have never been demonstrated (Holloway 1954; Lagler et al. 1942).

Gars are sought by anglers with hook and line, snare, and spears in various areas and are not protected by any regulations.

Nomenclature

Esox osseus — Linnaeus 1758: 313 (type locality Virginia)
Lepisosteus Huronensis — Richardson 1836: 237
Lepisosteus rostratus, Nob. — Cuvier *in* Richardson 1836: 238
Lepisosteus bison — DeKay 1842: 271
Lepidosteus Huronensis — Forelle 1857: 283
Lepisosteus longerostris Cuvier — Fortin 1865: 67
Lepodosteus piquotianus — Duméril 1870: 323
Lepisosteus osseus Günther — Jordan and Evermann 1896–1900: 110
Lepidosteus osseus Linnaeus — Halkett 1913: 45
Lepisosteus osseus oxyurus Rafinesque — Jean 1946: 100

Etymology *Lepisosteus* — scales of bone; *osseus* — bony.

Common names Longnose gar, northern longnose gar, garpike, common garpike, gar, billfish, northern mailed fish, needlenose. French common name: *lépisosté osseux*.

Suggested Reading – Lepisosteidae

AGASSIZ, L. 1850. Lake Superior. Its physical character, vegetation and animals compared with those of other and similar regions. Gould, Kendall and Lincoln. Boston, Mass. 428 p.

EYCLESHYMER, A. C. 1903. The early development of *Lepidosteus osseus* (with bibliography). Publ. Univ. Chicago 10: 259–275.

LAGLER, K. F., D. B. OBRECHT, and G. V. HARRY. 1942. The food and habits of gars (*Lepisosteus* Spp.) considered in relation to fish management. Invest. Ind. Lakes Streams, Ind. Dep. Conserv. 2: 118–135.

NETSCH, LT. NORVAL F., and A. WITT, JR. 1962. Contributions to the life history of the longnose gar, (*Lepisosteus osseus*) in Missouri. Trans. Amer. Fish. Soc. 91: 251–262.

SUTTKUS, R. D. 1963. Order Lepisostei, p. 61–88. *In* Fishes of the western North Atlantic. Mem. Sears Found. Mar. Res. 1(3): 630 p.

THE BOWFIN — Order Amiiformes

Stout bodied, oval, but somewhat laterally compressed, archaic, predatory fishes. A transitional group close to the gars but showing many characteristics leading to the higher teleost fishes. The head is rounded; the snout not produced. The toothed, lower jaw is a complex of many bones, and articulates with the ethmoid region of the skull. The ventral surface of the lower jaw has a large, characteristic, bony, gular plate. The fins are without spines. The rounded caudal fin is actually abbreviate heterocercal as in the earlier lepisosteans. Vertebral centra, when present, are double concave or amphicoelous (unlike the gars) and, in the tail region of some, diplospondylous (2 centra per vertebra). Fishes in this order have ganoid or cycloid, overlapping scales; fulcra are present, reduced, or absent.

Bowfins are known from the Upper Permian to the Recent of Asia, Europe, and North America. There is only one living family, Amiidae, which is restricted to North America.

Depending on the authority, there is a minimum of 6 and a maximum of 11 families in the order. Their transitional status, in relation to higher teleosts, and the changing concept of the relation of the amiids to other primitive groups, especially the gars, is demonstrated in the variety of ways in which they have been classified in the past. We utilize the concept (Berg) that 6 amiid families stand alone in the order Amiiformes adjacent to, but separate from, the gars.

BOWFIN FAMILY — Amiidae

This family constitutes the only living representatives of the order Amiiformes. *See* the description of the order for basic characteristics.

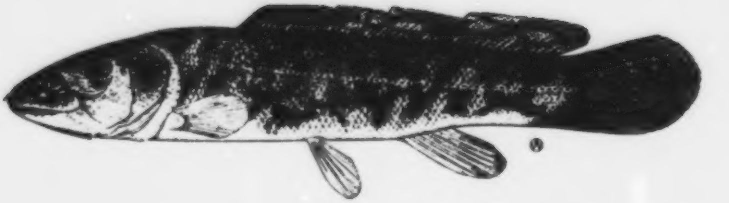
Bowfins are moderately large, oval, predatory fishes, with rounded, naked, bony heads, and bodies covered with cycloid scales. The mouths are well armed with pointed teeth. The possession of a bony, gular plate between the lower jaws is unique in Canadian freshwater fishes. The caudal fin is rounded and abbreviate heterocercal; the dorsal fin long. The swim bladder is physostomous, vascularized, and capable of assimilating atmospheric oxygen.

This primitive family is now represented by a single, living species, *Amia calva*, which is restricted to the fresh waters of eastern North America.

Fossil members of the family are known from the Tertiary of Europe and Tertiary to the Recent of North America.

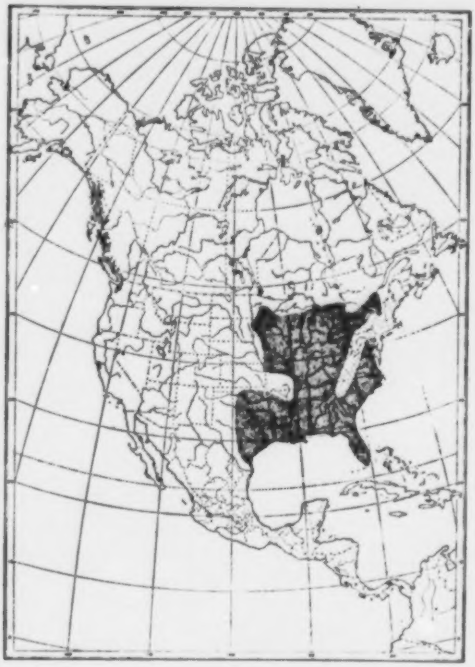
BOWFIN

Amia calva Linnaeus



Description The bowfin has a moderately long, deep, robust body, greatest depth 14.2–19.7% of total length, body laterally compressed, cylindrical to oval in cross section near head. Those commonly seen are 18–24 inches (457–610 mm) in length and 2–3 pounds in weight. The head is massive, rounded, broad, naked, and bony, head length 21.9–24.1% of total length; eye small, diameter 30.5–38.5% of snout length; snout short, 5.9–7.3% of total length, bluntly rounded, with the nostrils well separated and the anterior pair opening through short, barbel-like tubes; interorbital width 25.9–29.8% of head length; mouth large, maxillary extending well past the eye; teeth varying from strong, pointed canines to shorter and peglike, present on premaxillary, maxillary, vomer, palatine, ectopterygoid, and on the dentosplenial coronoids and prearticular of the lower jaw. A unique character of this species, among Canadian freshwater fishes, is the heavy, oval, bony gular plate within the angle of the lower jaw. Branchiostegal rays 10–12, wide, bladelike; gill rakers mere knobs with denticles. The naked cheek, opercular bones, and the fleshy opercular flap are all wide. Fins: a single, very long, low dorsal with 46–50 soft rays, origin about 33% of total length and ending near caudal, base 42.7–47.5% of total length; virtually no caudal peduncle separating dorsal and caudal; caudal large, rounded, abbreviate heterocercal; caudal peduncle deep, greatest depth 11.0–13.2% of total length; anal with 9 or 10 rays, situated at midpoint of dorsal but base length only 14.3–20.2% of dorsal; pelvics small, rounded, and at midpoint of body; pectorals low, large, rounded, with 16–18 rays. Scales large, soft, and fleshy, "polygono cycloid," 64–68 in lateral line; lateral line complete; no pyloric caeca but gut with rudimentary spiral valve; physostomous, swim bladder bifid in front, cellular, and respiratory in function. Anterior vertebrae higher than wide, dense, amphicoelous, little sculpturing. One specimen from Lake Ontario had 80 vertebrae and one from Lake Erie had 87.

Colour Dark olive somewhat lustrous above, lighter on sides and below, the mingling of lighter yellow and darker olive giving a marbled or reticulated pattern, less so in females; belly cream to white; head yellow to brown with darker horizontal bars; dorsal fin dark olive with narrow darker bands crossing it, caudal light olive with irregular, broken, darker, vertical bars; at base of upper caudal rays a round to oval black spot twice the size of the eye, prominent in males and a yellow to orange halo, in females no halo and inconspicuous to absent; anal and paired fins bright green, often with orange at base and tip in males, and olive overall, without the orange in females; young individuals less than 8 inches (203 mm) in length are lighter in colour, light olive to apple-green, with dorsal and caudal tipped with narrow, black edge; snout, eye, cheek, and opercle crossed by a narrow-dusky stripe (Forbes and Richardson 1920).



Distribution The bowfin occurs only in North America, from the St. Lawrence River–Lake Champlain drainage of Quebec and Vermont west across southern Ontario to the Mississippi drainage in Minnesota. In the east it extends southwest of the Appalachian Mountains to Florida, on the Atlantic coast from the Susquehanna River to Florida, but introduced in Connecticut. In the west it extends south through the eastern part of the states of South Dakota, Nebraska, Kansas (northeastern part only), and Missouri, to central Oklahoma and Texas.

In Canada it occurs in Quebec and Ontario in the upper St. Lawrence River (Lake St. Peter), Lake Champlain, Ottawa River, all the Great Lakes as far up as St. Joseph's Channel of lower Lake Superior, and in lakes Nipissing and Simcoe. Northward expansion of the range in Canada is possibly limited by temperature requirements, since distribution is south of 65° F (18.3° C) isotherm (Radforth 1944).

Biology The published information on this species in Canada is limited to some notes on its life history in Georgian Bay given by Bensley (1915), and growth data for Quebec published by Cartier and Magnin (1967). Otherwise we must turn to publications based on populations in Michigan and farther south.

The bowfin is a spring spawner. Bensley (1915) gave the spawning time in Georgian Bay as from May 24 to June 1, but they spawn as early as late April farther south. The males at this time move into shallow, vegetated water in lakes and rivers and prepare a nest. The nests, in 1–2 feet (305–610 mm) of water, are circular areas from which all leaves and stems are bitten off or torn out and removed, or are under logs, stumps, or bushes, and are 15–24 inches (381–610 mm) in diameter. The concave bottom contains the roots of the cut vegetation. Number and proximity of nests varies directly with the amount of suitable spawning territory. The male defends a small territory around the nest against other males, and torn fins suggest very aggressive defense. Optimum temperature for nest construction and spawning is 60.8°–66.2° F (16.0°–19.0° C) (Reighard 1904). A female is attracted into the nest and spawning takes place apparently during day or night. The female lies on the bottom of the nest, the male circles about her for 10 or 15 minutes, sometimes nipping her snout or sides. The male then takes up a position beside the female, there is a violent agitation of the fins of both fish, and eggs and milt are at this time released over a period of less than 1 minute. There are brief periods of circling and spawning, such that in 100 minutes four or five batches of eggs are laid. There are often three times as many males as females on the spawning grounds. More than one female may spawn with the same male in a single nest, and females may deposit eggs in more than one nest, so that a nest often contains eggs in different stages of development. The eggs are adhesive and stick to the bottom of the nest (Reighard 1900). A female bowfin 5 pounds in weight contained 23,600 eggs and a female 21 inches (533 mm) in length contained 64,000 eggs

(MacKay 1963). The eggs are creamy yellow when first laid but have been said to darken quickly and are then hard to see. The male guards the nest and maintains a current of water over the eggs by the motion of the pectoral fins. The young hatch in 8–10 days and are at this time 8 mm long. They have an adhesive organ on the tip of the snout by which they remain attached to vegetation for 7–9 days at which time they are 10–13 mm long. Mansueti and Hardy (1967) illustrated and described larval stages in the Chesapeake Bay region. Many authors, including Kelly (1924) and Doan (1938), have described the behaviour of males guarding a compact school of 30–40 (Doan 1938) to 1000 (Migdalski 1962) individuals for several weeks, up to the time they are 4 inches (102 mm) in length. The males at this time are pugnacious and, if forced to flee, drive the young down in a protecting cloud of silt created by their own departure. The young grow quickly and, in the United States, are 5–9 inches (127–229 mm) in length by October (Carlander 1969).

The age–length relation of the bowfin was for a long time unavailable as it was considered that age could not be determined from the scales. Cooper and Schafer in 1954 published age–length data for Michigan, and Cartier and Magnin in 1967 gave records for the Montreal region, using scales, gular plates, and otoliths. Cartier and Magnin also gave the following growth formula for all individuals: $\log L = 2.35137 + 0.59922 \log A$, where L = total length in mm and A = the age-group, and demonstrated the validity of back calculation of size at various ages. The age–observed length data are as follows:

Age	Observed length	
	(inches)	*(mm)*
1	8.7–9.3	221–236
2	14.9–15.6	378–397
3	16.2–19.0	412–482
4	16.2–23.8	412–605
5	20.1–25.2	511–640
6	21.3–24.2	541–615
7	24.6–28.3	624–718
8	26.1–27.3	662–693
9	25.2	640

They gave the weight–length expression as $\log W = -4.961 + 2.992 \log L$, where W = weight in g and L = length in mm, and the age–observed weight relation as follows:

Age	Observed weight	
	(lb) approx	*(grams)*
1	0.29–0.34	132–153
2	1.0–1.6	469–722
3	1.7–2.5	775–1150
4	1.5–4.7	675–2150
5	2.7–6.5	1255–2900
6	3.4–6.5	1539–2900
7	5.8–8.2	2605–3750
8	8.3–8.6	3760–3900
9	6.1	2750

Sexual maturity is thought to be reached at 3–5 years, at about 24 inches (610 mm) in females and 18 inches (457 mm) in males. Males are always smaller than females and probably do not live so long.

Maximum size in Quebec was given as 34.2 inches (870 mm) and approximately 15 pounds (6800 g), but this maximum weight appeared nowhere in the tabular or graphic presentation of weight data. The bowfin seen in Canada are usually 18–24 inches (457–610 mm) in length and 2–3 pounds in weight. Maximum age, it was suggested, was 12 years in Quebec but Carlander (1969) quoted ages of 20, 24, and 30 years for bowfin in captivity.

The habitat of the adults is swampy, vegetated bays of warm lakes and rivers. The capability of gulping air at the surface and withstanding high temperatures enables this species to succeed in stagnant areas in which other large predatory fish are unable to survive. The fact that the young are rarely seen after the schools break up suggests they move to deeper water or to dense vegetation. Neill in 1950 reported having unearthed an aestivating bowfin in a moist chamber 4 inches (102 mm) below the surface and 8 inches (203 mm) in diameter, ½ mile from a river, the flood level of which had previously reached the location of the chamber.

Observations in aquaria suggest the bowfin is a slow, clumsy, stalking predator that uses scent as much as sight and captures food by means of a sudden intake of water.

The food of the bowfin is largely other fishes, crayfish, and frogs, although Breder (1928) reported individuals up to 17¾ inches (450 mm) in length in Mississippi had eaten mostly insects such as water boatmen, whirligig beetles, and dragonfly nymphs, the small shrimp *Palaemonetes exilipes*, and appreciable amounts of vegetation. Scott (1938) listed bluegills, *Lepomis macrochirus*; rock bass, *Ambloplites rupestris*; catfish, *Ictalurus*; pickerel (*Esox*); yellow perch, *Perca flavescens*; and bowfin, *Amia calva*. Lagler and Hubbs (1940) qualified stomach contents by volume as 59% game and pan fish (perch, catfishes, and sunfishes), 17.1% other fishes (mainly minnows), and 14.1% crayfish. They listed the following additional species of fish food: yellow bullhead, *Ictalurus natalis*; smallmouth bass, *Micropterus dolomieui*; largemouth bass, *Micropterus salmoides*; longear sunfish, *Lepomis megalotis*; pumpkinseed, *Lepomis gibbosus*; gizzard shad, *Dorosoma cepedianum*; carp, *Cyprinus carpio*; central mudminnows, *Umbra limi*; grass pickerel, *Esox americanus vermiculatus*, and Iowa darter, *Etheostoma exile*. They included 0.1% volume of carrion, so bowfin are obviously not significant scavengers. Insect forms listed were dragonfly, damselfly, caddisfly, soldierfly, and beetles. That it is an opportunist rather than a selective predator, as well as a voracious feeder, is exemplified by the fact that 84% of its food was gizzard shad in a Florida lake overpopulated by this species (Berry 1955). It takes (experimentally) approximately 32 hours for a young-of-the-year bowfin to digest a single fish at 69.8° F (21.0° C) and at 79.2° F (26.2° C) the daily average ration of this size bowfin is 6.48% of body weight (Herting and Witt 1968). Aquarium observations of feeding show that adult bowfin often gorge on food when it is available in excess and, at this time, pass partly digested particles in the faeces, making insufficient use of food consumed.

There is apparently no information available on the predators of this species other than the fact that they appear in the food of the same species. They eat a range of fishes comparable to most other predatory fishes including several sport fishes. Their usual habitat is often unsuitable for sport fishes so that the true extent to which they compete with more valued species is not readily ascertained.

The parasites of *Amia calva* were listed in detail by Hoffman (1967) and these included 38 species as follows: Trematoda (16), Cestoda (8), Nematoda (6), Acanthocephala (4), leeches (1), Crustacea (2), and *Linguatula* (1).

Relation to man As with the gars, the bowfin, a voracious, piscivorous predator, is usually considered a pest since little commercial or recreational use is made of it, and since it consumes the same food as several more valued warmwater species. It may constitute a more serious direct predator on, and competitor of, sport fishes in Canada than it does in the south. Here the opportunity for it to utilize waters too hot and too deoxygenated for other forms is not so readily available and the bowfin and the sportfishes may more often be in the same areas of lakes or streams.

It is used as food to a limited extent in the south but not at all in Canada. The flesh, although edible, is very soft and jellylike and not considered of much value. Recent commercial catches in Canada are masked as they are grouped with several other species. MacKay (1963) listed the commercial catch in Ontario in 1956 as 77,000 pounds with a value of $2205, or an average of just over 2¢/pound. All of this was shipped to the United States. MacKay (1963) stated that the flesh can be made passably palatable by marination in spices and vinegar before cooking, by smoking, or by baking in highly seasoned dressing. Migdalski (1962) stated that the flesh is dry, has a mild flavour and when moulded into patties, dipped in egg and bread crumbs or corn meal, it makes passably good eating.

Although largely ignored as a sport fish it readily takes live bait and lures that are fished on the bottom. It provides considerable sport when taken on a light tackle. The bowfin is one of the few species that anglers and divers are permitted to spear as there are no regulations governing their capture.

The bowfin is usually considered detrimental to sport fish habitats. As a consequence of its appetite and diet, it may at times be a beneficial control on other species not favoured by man, as discussed by Berry (1955).

The small individuals make interesting and easily maintained aquarium subjects.

Nomenclature

Amia calva — Linnaeus 1766: 500 (type locality Charleston, South Carolina)
Amia ocellicauda (Richardson) — Richardson 1836: 236
Amia occidentalis — DeKay 1842: 269
Amia canina — Cuvier and Valenciennes 1846 (1828–1849): 424
Amia ocellicaudata Richardson — Fortin 1866: 76
Amia thompsoni — Duméril 1870: 419
Amia ocellicaudata — Desrocher 1904: 38

Etymology *Amia* — an ancient name of a fish, possibly the bonito *Sarda sarda*; *calva* — smooth.

Common names Bowfin, dogfish, freshwater dogfish, mudfish, western mudfish, cottonfish, blackfish, John A. Grindle, grindle, grinnel, speckled cat, beaverfish, lawyer, scaled ling, choupiquel, poisson de marais. French common name: *poisson-castor.*

Suggested Reading – Amiidae

CARTIER, D., et É. MAGNIN. 1967. La croissance en longueur et en poids des *Amia calva* L. de la région de Montréal. Can. J. Zool. 45: 797–804.

FORBES, S. A., and R. E. RICHARDSON. 1920. The fishes of Illinois. Natur. Hist. Survey Div., State Ill. 357 p.

REIGHARD, J. E. 1904. The natural history of *Amia calva* Linnaeus, p. 57–109. *In* Mark Anniversary Volume, No. 4. New York, N.Y.

THE HERRING-LIKE FISHES — Order Clupeiformes (Isospondyli)

The Clupeiformes are terete-bodied, elongate fishes, only moderately, laterally compressed; the body shapes of the Atlantic herring and salmons typify the appearance of the whole group; the head is well developed, covered with thin, membrane bones that are not well fused together; jaws may be weak, with minute or small, weak teeth, or may be well developed with strong teeth, the upper jaw usually bordered by premaxillary and the maxillary. Branchiostegal rays 1–36 and variously arranged. All fins without spines, always 1 rayed dorsal fin but, in addition, there may be an adipose dorsal fin located over, or slightly in advance of, the caudal peduncle; caudal fin extremely homocercal, internally the posterior 2 or 3 vertebrae may be upturned; 1 anal fin; pelvic fins abdominal and with many rays, pelvic girdle not attached to cleithra; pectoral fins located ventrally behind the head, the bases nearly or quite horizontal, and many rays. Scales small to large and cycloid or absent. Physostomes. Vertebrae numerous and not graduated in size, the earlier ordinal name, Isospondyli, is of Greek origin and means "equal vertebrae."

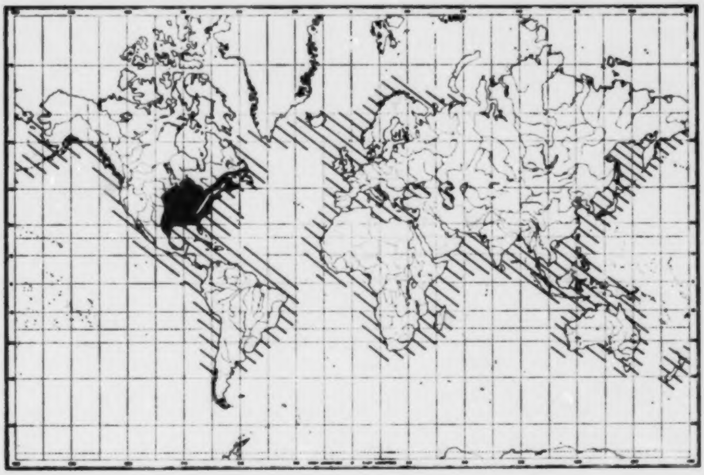
The clupeiform fishes are widely distributed through the world seas and in the fresh waters of the northern hemisphere. The order may be classified into as many as 9 suborders, 33 families, and over 900 species. Economically, this is the most important order of fishes occurring in Canadian fresh waters, and in terms of dollars and cents, is probably the most valuable group of fishes in the world.

HERRING FAMILY — Clupeidae

The herrings are of small to medium size, body usually slender, distinctly laterally compressed in most species; eyes with conspicuous adipose eyelids; mouth small to moderate, not large, jaws usually terminal, teeth small or absent. Gill rakers long, slender, and numerous. Scales confined to body, deciduous, cycloid, and with circuli arched across scale rather than in concentric rings; midline of belly, anterior to pelvic fins, often reduced to knife-edge thinness and armed with scutelike scales forming a saw-toothed edge. Lateral line absent. Adipose fin absent. Swim bladder thin walled. Pyloric caeca numerous. Vertebrae, total for Canadian species number about 39–59.

The herrings are silvery, pelagic fishes, primarily marine, but many species are anadromous and a few species live permanently in fresh water. They occur throughout the world's seas, except in antarctic waters.

The Clupeidae is a large family, containing approximately 190 species. Four species in 2 genera occur in Canadian fresh waters.



World Distribution of the Herrings

KEY TO SPECIES

1 Last ray of dorsal fin protracted into a long filament; snout rounded; mouth slightly subterminal; anal rays more than 25. .... GIZZARD SHAD, *Dorosoma cepedianum* (p. 133)

Last ray of the dorsal fin the shortest ray; snout more or less pointed; mouth terminal; anal rays fewer than 25 2

2 Lower jaw, when closed, nearly equal to upper, and fits into notch in upper jaw; maxillary extends at least to posterior margin of eye; gill rakers more than 55; usually 4–6 black spots in horizontal row behind operculum. .... AMERICAN SHAD, *Alosa sapidissima* (p. 128)

Lower jaw, when closed, extending beyond upper jaw; maxillary extends only to midpoint of eye; gill rakers fewer than 55; 1 prominent black spot near upper rear edge of operculum 3

3 Eye diameter usually greater than snout length; peritoneum silvery (otolith distinctive, *see* p. 121) .... ALEWIFE, *Alosa pseudoharengus* (p. 120)

Eye diameter usually smaller than snout length; peritoneum darkly pigmented (otolith distinctive, *see* p. 121) .... BLUEBACK HERRING, *Alosa aestivalis* (p. 119)

BLUEBACK HERRING

Alosa aestivalis (Mitchill)

Description The blueback herring is similar in shape and general appearance to the alewife, *Alosa pseudoharengus*, and is difficult to distinguish from it. The body is elongate, average length 8 inches (203 mm), compressed laterally and deep, its depth 22.1–25.2% of total length. Head broadly triangular, 18.5–20.6% of total length; eye moderate, adipose eyelid well developed, diameter of eye 22.0–26.4% of head length; snout length 23.4–30.0% of head length; interorbital 21.1–26.4% of head length; anterior end of lower jaw thick and rather heavy, extending beyond upper jaw when mouth closed and not fitting into groove in upper jaw; maxillary extending to below middle of eye; teeth small, weak, and few in number. Branchiostegal rays 7,7. Gill rakers 41–52. Fins: dorsal 1, height moderate, base short, 10.3–13.8% of total length, rays 16–18 (Hildebrand 1963, p. 325, said 15–20); caudal distinctly forked; anal 1, height relatively short, base long, 10.6–12.6% of total length, rays 15–17 (Hildebrand said 16–21); pelvic fins abdominal, rather small, length 8.4–10.0% of total length, rays 10 or 11; pectorals low on sides, length 13.0–15.0% of total length, rays 17 or 18 (Hildebrand said 14–16). Scales large, silvery, deciduous; lateral line not developed, scale rows 41–46. Ventral scutes well developed, pre-pelvic scutes 18–20, post-pelvic scutes 12–16. Pyloric caeca numerous. The colour of the peritoneum in the blueback herring is sooty to black as opposed to the pearly-grey peritoneum of the alewife. This is the most reliable character for distinguishing the two species except for otoliths, *see* p. 121. Vertebrae 49–51.

Colour The overall colouration is silvery but the back is greyish, blue-green, or dark blue, from whence the name blueback is derived. The sides and belly exhibit a silvery colour; peritoneum (lining of belly) sooty or blackish.

Distribution The blueback herring reaches its northern limit in Canadian waters and occurs along the eastern North American coast southward from Cape Breton, Nova Scotia, and the Fundy watershed of New Brunswick, to an area of relative abundance along the New England coast; thence as far south as northern Florida.

In Canada the species is not common. Specimens are known from the Bras d'Or Lakes on Cape Breton Island, in the Shubenacadie and Stewiacke rivers in Nova Scotia, and specimens were collected in the Kennebecasis River, King's County, N.B., in June 1967, and in the summer of 1968. The species occurs in other rivers such as the Saint John, but is not readily distinguished from the alewife.

Biology The blueback herring is an anadromous species, spending most of its life in salt water and returning to fresh water to spawn sometime in spring. It usually spawns in warmer water than the alewife and its spawning migration is correspondingly later. Various authors consider that this species does not go above brackish water for spawning purposes; others have indicated that it spawns in fresh water. As it does not ascend the freshwater streams as far as does the alewife, its spawning occurs nearer to the sea.

The large number of eggs, each about 1 mm in diameter, sinks to the bottom and adheres to sticks, stones, gravel, or other objects with which they come in contact, as is also true for the alewife. The spent fish return to sea on completion of spawning. Incubation is rapid, requiring about 2–3 days at a temperature of 72°–75° F (22.2°–23.9° C).

The young fish grow quickly and when they are about a month old they are 30–50 mm long, at which size they seem to move quickly into the sea. Mansueti and Hardy (1967) illustrated and described larval stages in the Chesapeake Bay region. Although known to be schooling fishes, little is known of the habits or growth of bluebacks at sea. They are caught along with alewives but generally not distinguished from them. There is some evidence that they may winter near the bottom. They grow to a size of 15 inches (380 mm) and a weight of about 13 ounces.

Food consists of plankton, copepods, pelagic shrimp, and small fish fry, as well as fish eggs and larvae.

Sumner et al. (1913) listed the acanthocephalan *Echinorhynchus acus* as a parasitic form infesting the blueback, and Gudger (1937) reported a specimen from Beaufort, N.C., with a large colonial hydroid, *Obelia commensuralis*, attached to its back.

Relation to man In Canada the blueback is caught commercially along with the alewife and generally processed or utilized in the same manner as that species. No special fishery or processing has been developed.

Nomenclature

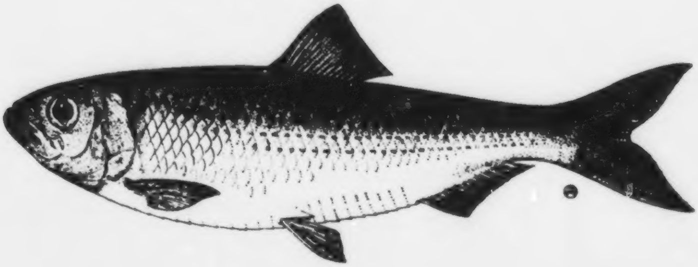
Clupea aestivalis — Mitchill 1815a: 456 (type locality New York)
Alosa cyanonoton Storer — Storer 1857: 266
Pomolobus aestivalis (Mitchill) — Jordan and Evermann 1896–1900: 427
Pomolobus cyanonoton Storer — Bean 1903a: 403
Alosa aestivalis (Mitchill) — Bailey et al. 1970: 15

Etymology *Alosa* — Saxon "allis," old name of the European shad *Alosa alosa; aestivalis* — of the summer.

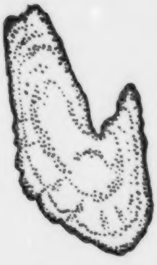
Common names Blueback herring, mulhaden, glut herring, blueback, summer herring, blackbelly, kyack. French common name: *alose d'été*.

ALEWIFE

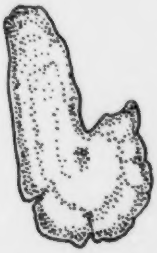
Alosa pseudoharengus (Wilson)



Description Body small, average length 6 inches (152 mm), strongly compressed laterally, and rather deep, its depth 17.8–21.7% of total length. Head broadly triangular, 20.3–23.7% of total length; gill membranes free; eye large, its diameter 26.1–32.0% of head length, adipose eyelid well developed; snout moderate, its length 26.9–35.7% of head length; interorbital width 15.7–21.6% of head length; anterior end of lower jaw thick and rather heavy, extending beyond upper jaw when mouth closed and not fitting into groove in upper jaw; maxillary extending to below middle of eye; teeth small and weak and few in number on premaxillary and mandible. Gill rakers on lower limb 38–43. Branchiostegal rays 7,7 (rarely 7,6 or 6,7). Fins: dorsal 1, height moderate, base short, 13.6–17.7% of total length, rays 12–16, usually 13 or 14; caudal distinctly forked; anal 1, height comparatively short, base long, 10.3–12.0% of total length, rays 15–19, usually 17 or 18; pelvics abdominal, rather small, length 8.2–11.6% of total length, rays 10; pectorals low on sides, length 13.0–16.6% of total length, rays 14–16, usually 16. Scales large, silvery, deciduous; lateral line not developed but scale rows about 42–50 along side; ventral scutes well developed, pre-pelvic scutes 17–21, usually 19 or 20, post-pelvic scutes 13–16, usually 14 or 15 — enumeration of scutes according to method described by Miller (1950a). Pyloric caeca numerous. Vertebrae 47–50 (Great Lakes 47–49, Atlantic coast 48–50). The shape of otoliths of *A. pseudoharengus* and *A. aestivalis* can be useful in identification. *See* outlines below.



A. aestivalis

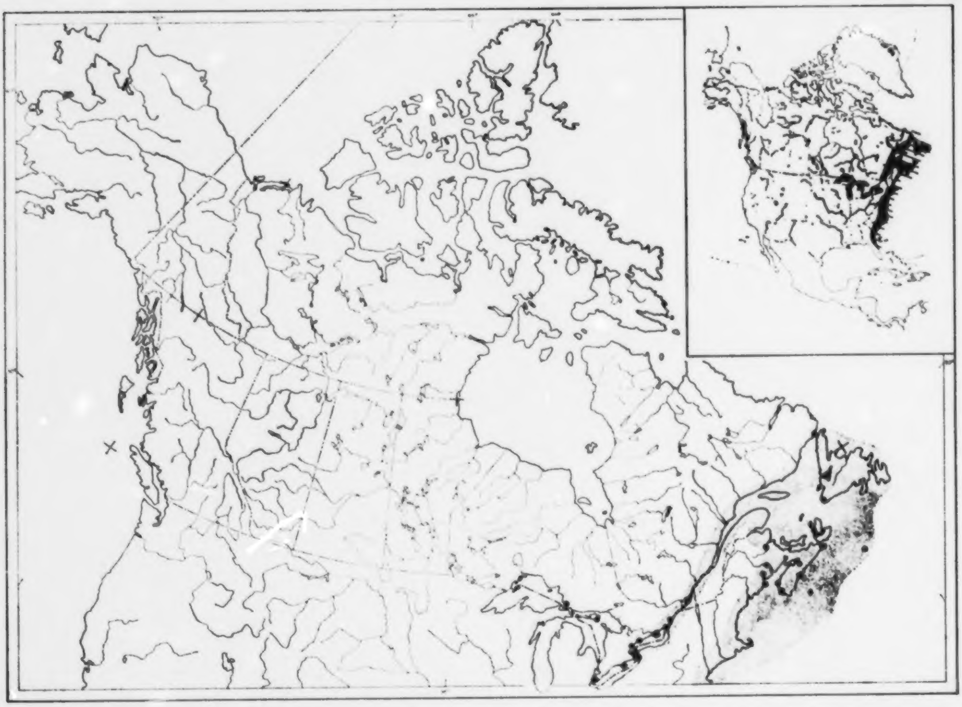


A. pseudoharengus

Colour The overall colouration of the alewife is silvery, the back greyish green and the sides and belly silvery, and iridescent when freshly caught. Adults sometimes have dark, longitudinal lines along the scale rows above the midline of the sides. Small specimens have a violet sheen on the silvery sides. Sea-run individuals have a golden cast on the head and upper parts but this is lost when in fresh water. A single black spot is present at eye level, immediately behind the head. The lining of the body cavity is pale to dusky.

Distribution The alewife is an anadromous species of eastern North America, a marine fish that uses freshwater streams for spawning and, hence, is indigenous to the lakes and streams of the Atlantic coastal drainage from Newfoundland to North Carolina. It is now landlocked in many inland lakes; in Ontario such lakes as Otter and Red Horse in Leeds County, the Rideau waters above Kingston Mills (Toner 1934), and throughout the western Rideau waters. Toner recorded the species from Gananoque Lake, Gananoque River, South Lake, Charleston Lake, Wiltsie Creek, from lower Beverly Lake (Toner 1937, 1938), in Kingston harbour, and in the St. Lawrence River below Kingston in 1941. In New York State it is also landlocked in Onondaga, Cayuga, and Seneca lakes, the Oswego River system, Ballston and Round lakes, and others. The greatest number of landlocked populations, however, occurs in the Great Lakes themselves. Presumably originating from Lake Ontario populations, the alewife now occurs in all of the Great Lakes, reaching extreme abundance in some years.

Much has been written regarding its abundance in fresh water, especially in the Great Lakes where the annual die-offs present serious disposal problems. First reported in Lake Ontario in 1873 (Bean 1884a), it became abundant in the late 1800's (Wright 1892). How the alewife became established in Lake Ontario is uncertain but it has been suggested that this resulted from its accidental inclusion with a planting of American shad, *Alosa sapidissima*, about 1870 (Bean 1884a). Smith (1892), in his report on the investigations of Lake Ontario fisheries, dismissed this theory since alewives were already present in Seneca and Cayuga lakes in New York State before shad planting began,



and could have migrated to Lake Ontario through certain lakes and water routes in that State, or even by ascending the St. Lawrence River. Radforth (1944) theorized that "... because the invasion of the Champlain Sea is held responsible for the occurrence of other marine species such as the smelt and shad in certain eastern waters, it is not improbable that the presence [of the alewife] in Lake Ontario may also be attributed to the marine invasions," or the alewife may be a native species, established when Lake Ontario was much higher and covered the entire Rideau lakes area, where they now occur in some lakes.

S. H. Smith in his study of the invasion and ecologic impact of the alewife in the Great Lakes (personal communication 1970) discussed in detail the theories of the alewife's entrance into Lake Ontario, and discounted the theory of accidental planting. He summarized as follows: "... there is convincing evidence that the major influx of alewives that contributed to the sharp population increase in Lake Ontario during the 1870's originated from downstream movement of alewives that were increasing sharply in the waters of the Erie Canal system in the 1860's. There is no reason to believe, however, that there was not at least some natural entrance from populations that long had access to the lake, or that some alewives had been accidentally introduced with plants of Atlantic shad fry. All evidence indicates, however, that alewives from these sources would have been too few, or too late to account for the population explosion in the 1870's."

Movement from Lake Ontario to the upper Great Lakes appears to have been exceedingly slow and was not detected until the first specimen was caught in 1931 and reported by J. R. Dymond in 1932. Niagara Falls presents an insurmountable barrier to all fish species attempting to move from Lake Ontario into the upper lakes, but the Welland Canal was completed in 1824, and the Erie Barge Canal, connecting the Hudson and Mohawk River systems with Lake Erie, in

Spread of the alewife in the upper Great Lakes, (modified from Miller 1957)

Date	Locality	Remarks[a]
Sept. 23, 1931	L. Erie, at E end off Nanticoke, Ont.	Adult, 7¾ inches long (Dymond 1932a)
Mar. 28, 1933	L. Huron, 12 miles E of Outer Duck Is., Ont.	Adult, from about 70 fath; others reported (MacKay 1934)
Apr. 15, 1935	L. Huron, 40 miles from Rogers City, Mich.	Adult, 188 mm SL, from 70 fath; UMMZ 109109 (Van Oosten 1935)
Dec. 26–31, 1940	L. Erie, off South Bass Is., Ohio	Adult, 9 inches TL, taken in gillnet by K. H. Doan (Trautman 1957)
May 5, 1949	L. Michigan, W of S Manitou Is., Mich.	Adult, 176 mm SL, from 60 fath, C. Anderson; UMMZ 157215
Mar. 20, 1951[b]	L. Michigan, off Whitehall, 14 miles SW of Montague, Mich.	Adult, 197 mm SL, from 60 fath, J. Grover; UMMZ 160969 (*see The Fisherman*, Vol. 19, No. 5, 1951, p. 6)
Mar. 12, 1952	L. Michigan, 10 miles ENE of Milwaukee, Wisc.	Adult, 177 mm SL, F. Miller; UMMZ 162861
July 14, 1953	L. Erie, South Bass Is., Ohio	Young-of-the-year (Langlois 1954, p. 207)
Dec. 22, 1953[c]	L. Michigan, 12 miles WNW of South Haven, Mich.	Adults, 180 and 188 mm SL, from 32 fath, C. Jensen; UMMZ 166514
Sept. 25, 1954	L. Superior, off Pendill's Cr., Chippewa Co., Mich.	Adult, 168 mm SL, R. Gordon; UMMZ 167872
Nov. 1954	L. Superior, Chequamegon Bay, off Long Is., Wisc.	Adult, 164 mm SL, obtained by R. Daly; UMMZ 167945
June 1 & 14, 1955	L. Superior, Whitefish Bay, about 1 mile N of mouth of Tahquamenon R., Mich.	Adults, 162 and 175 mm SL, from poundnet, E. L. Pomeroy
June 3, 1955	L. Huron drainage: Ocqueoc R. Weir near Rogers City, Mich.	Adults, 179 and 182 mm SL, A. E. Hall, Jr.; UMMZ 169062
June 11, 1955	L. Michigan, East Bay of Grand Traverse Bay, Mich.	19 juveniles. 55–76 mm SL, bait dealer for S. Lievense; UMMZ 170945
Sept. 14, 1955	L. Huron, along shore in the Les Cheneaux Channels, Mackinac Co., Mich.	Fingerlings, about 2 inches TL, bait dealer; identified by L. R. Anderson
Oct. 17 & Nov. 12, 1955	L. Superior, Gros Cap area near Sault Ste. Marie, Ont.	Adult male, 210 mm TL, and adult female, 273 mm TL, identified by K. H. Loftus and W. B. Scott; ROM 18157 (male)
Feb. 13, 1956	L. Superior, off Two Harbors, Minn.	Adult from herring net, Adolph Ojard; identified by J. G. Hale and S. Eddy
Mar. 1956	L. Superior, off Knife R., Minn.	Adult taken by I. Pederson; identified by J. G. Hale
June 6, 1956	L. Superior, at mouth of Blind Sucker R., Luce Co., Mich.	Adult, 9½ inches long, caught by G. McGary; 2 other adults also taken. Identified by L. R. Anderson
July 31, 1956	L. Superior, Split Rock R. area, Minn.	Adult, 161 mm SL, from herring net, Ragnivald Sve
Aug. 31, 1956	L. Superior, off Shaganance Is., (near entrance to Black Bay), Ont.	Adult male, 166 mm SL, taken by M. Gerow; identified by R. A. Ryder
Sept. 10, 1956[b]	L. Michigan, East Bay of Grand Traverse Bay at O-at-ka Beach, Mich.	341 postlarvae to young, 19–40 mm SL, taken in minnow seine for S. Lievense; UMMZ 171308
Nov. 5, 1956	L. Superior, Keweenaw Bay, 1 mile off town of Keweenaw, Mich.	Adult, 181 mm SL, from surface gillnet over 17 fath, taken by U. Weideman

[a] Abbreviations SL, standard length; TL, total length; UMMZ University of Michigan Museum of Zoology; ROM, Royal Ontario Museum.

[b] Approximate date.

[c] On Apr. 24, May 10, and Oct. 20, 1954, three more adults were taken in 32–50 fath by Mr. Jensen from the same general area; UMMZ 167702.

1825. Although it seems most probable that the alewife entered Lake Erie via the Welland Canal, it is also possible that entry was gained via the Erie Barge Canal.

The spread of the alewife through Lake Erie and upper Great Lakes has been the subject of much study since it provided a rare opportunity to observe the rapidity with which a species could invade and occupy a new environment. Dr R. R. Miller in 1957 provided a comprehensive review of the dispersal of the alewife and the preceding summary, modified from his data, traces the spread of this species in the upper Great Lakes. Some of the specimens listed are preserved in the University of Michigan Museum of Zoology (UMMZ) and one is in the Royal Ontario Museum (ROM).

By 1942 it was common in Lake Erie but did not become a dominant species, possibly because of the lack of deep water where it could overwinter to avoid the cold, and also because of the presence of large populations of predator species.

It appeared in Lake Huron in 1933 (MacKay 1934), where it became abundant. A measure of the rapidity of increase in Lake Huron can be seen from the following quotation from Scott (1963): "An appreciation of the rate of increase of the numbers of this species in Lake Huron may be gained from the following production figures for the experimental fishery operated on South Bay, Manitoulin Island, by the Ontario Department of Lands and Forests. The fluctuations in total catch from 1957 onward probably reflect variation in gear and fishing effort rather than fluctuations in population.

1951 — 1 specimen (4 oz)
1952 — 5 specimens
1953 — 53 specimens (6 lbs)
1954 — 2316 pounds
1955 — 16,302 pounds
1956 — 22,428 pounds
1957 — 19,045 pounds
1958 — 41,655 pounds
1959 — 28,540 pounds
1960 — 19,154 pounds
1961 — 40,563 pounds
1962 — 32,974 pounds
1963 — 24,666 pounds"

First reported in Lake Michigan May 5, 1949, the alewife is now the dominant species in the lake. The depletion by the sea lamprey of large predator fishes such as lake trout and burbot was probably an influential factor in the rapid increase in numbers of the small but prolific alewife. The Lake Michigan commercial fishery yielded 29 million pounds in 1966 and reached 40 million pounds in 1967. Many measures have been suggested to control the numbers of alewives, particularly because of the spring and summer die-offs. The recent introduction of the coho salmon, *Oncorhynchus kisutch*, into Lake Michigan waters is expected to have a marked effect on alewife numbers since coho feed heavily on alewives.

In 1945 the alewife appeared in Lake Superior but it is not particularly abundant there, possibly because it avoids water as cold as that of Lake Superior, and possibly because of predation by the lake trout and other large predator species.

Biology The marine populations of alewives spend most of their adult lives in the sea, entering fresh water to spawn in lakes and quiet stretches of rivers above the influence of the tide. Although they do not jump over obstructions, they can negotiate rapids and fishways and go farther upstream than their close relative the American shad, *Alosa sapidissima*. In the Miramichi River system in New Brunswick, spawning must take place largely in the river since there are few connecting lakes; in the Shubenacadie system in Nova Scotia they enter Grand or Shubenacadie lake, some spawning there, others moving on to Fletcher Run and Rawdon rivers.

Spawning migration from the sea is related to the water temperature of the river and hence takes place earlier in the southern part of the range. Leim and Scott (1966) stated that the migration begins in April and may last for 2 months in rivers tributary to the Bay of Fundy. Maturing alewives are caught in Saint John Harbour from late January but do not move up the river until early in April. The run is a little later in the rivers tributary to the Gulf of St. Lawrence. In the Margaree River, N.S., alewives appear first from May 4 to 27 and the run lasts from 1 month to 6 weeks. In the Maritime Provinces, where several commercial alewife fisheries are supported, spawning commenced in May and continued until late in June (Gillespie 1967).

The landlocked alewife inhabits the open lake waters during most of the year and moves onto the shallow beaches and into ponds to spawn. In Lake Ontario, Graham (1956) observed that the inshore movement of adult alewives from deep water began sometime in April, the precise time varying with the area. The greatest number arrived inshore about the middle of June in the Port Credit area of Lake Ontario where migration began in April and lasted until mid-July. In the Bay of Quinte region they were most abundant on the spawning grounds in late June and migration lasted until late July, again depending upon water temperatures.

Alewives move inshore at night and offshore during the daylight hours. Graham (1957) described the milling and "roller-coaster" movements of the schools when inshore. Females usually appeared on the spawning grounds first, with the males arriving soon afterwards. Spawning took place at night in groups of three or in pairs, over a sandy or gravelly bottom. The eggs were variously estimated from 10,000 to 12,000 from a freshwater female (Odell 1934). A sea-run female may produce on the average 60,000–100,000 eggs, the average size of the unfertilized egg being 0.9 mm in diameter (Mansueti and Hardy 1967). Eggs are broadcast at random, are demersal, and may be somewhat adhesive immediately after extrusion, but are essentially nonadhesive (Mansueti 1956). Hatching takes place in 6 days at a mean water temperature of 60° F (15.6° C) or in 3 days at 72° F (22.2° C). Mansueti and Hardy (1967) illustrated and described larval stages in the Chesapeake Bay region.

Graham (1956) observed that the adults left inshore waters immediately after spawning, most migrating to deep water sometime in late August. About mid-September they appeared in water 150–300 feet deep, reaching abundance by December and remained to overwinter in the deep water until March.

Juvenile alewives migrate inshore in spring, like the adults. They are found in shallow water at dark, and during the daylight hours are located on the bottom in 6–10 feet of water. It is probable that time of migration of juvenile alewives to deep water and duration spent there are similar to that of adult alewives.

The young remain on the spawning grounds until at least the late larval stage and then move slowly into protected areas on their way to deep water. By fall the young have attained a length of 2–3 inches (51–75 mm) (Smith 1907). Little is known of the life history of the alewife in the sea but size attained is usually about 10–12 inches (254–305 mm), occasionally 14 inches (356 mm).

Graham (1956) gave detailed information on the relative growth in different areas of Lake Ontario, and also a comparison with Atlantic specimens. The alewife in Lake Ontario displays rapid early growth, decreasing with the onset of maturity which occurs at age 2 for males and age 3 for females. Average length of the adult alewife in fresh water is about 6 inches.

Female alewives attain greater size than males and may live longer. Females also exhibit faster growth rate than males (Pritchard 1929). Rounsefell and Stringer (1943) reported Atlantic female alewives average 6–9 mm longer than males in Nemasket River in Massachusetts and in Demariscotta and Orland rivers in Maine. Males appeared to become sexually mature 1 year earlier than the females.

Atlantic alewives of both sexes mature one year later than the landlocked Lake Ontario alewives. Graham has also shown that the Atlantic alewife had a more rapid rate of growth throughout most of its life than the Lake Ontario alewife. It is suggested that freshwater environment hastens sexual maturity with the attendant inhibition of growth.

Alewives are basically zooplankton feeders, both as adults and young. In fresh water, the principal food organisms seem to be copepods, cladocerans, mysids, and ostracods. Insect larvae may be significant components in the diet of inshore adults. Algae, diatoms, and pieces of plant material have also been found in stomachs but Norden (1968) suggested that these may be ingested accidentally. In a detailed study of the food of larval alewives (5.9–6.1 mm total length) in Lake Michigan, Norden demonstrated that cladocerans (mainly *Bosmina*) and copepods (mainly *Cyclops* and *Limnocalanus*) constituted 75% or more of the organisms eaten and that a high degree of food selectivity was apparently exercised by the alewives. Morsell and Norden (1968) noted that landlocked adult alewives tended to eat zooplankton until about 4.7 inches (119 mm) long, but larger fish ate increasing numbers of the more benthic amphipod *Pontoporeia*.

Specimens from Minas Basin (upper Bay of Fundy) contained amphipods, mysids, and copepods, as well as small fishes and fish eggs.

Freshwater populations of alewives are preyed upon by the larger piscivorous fishes such as freshwater burbot and lake trout. Indeed the alewife was the main food supply of the Lake Ontario lake trout. As noted in the section entitled *Relation to man*, coho salmon, *Oncorhynchus kisutch*, introduced into Lake Michigan, are known to eat large quantities of alewives. Eels have also been reported to prey on alewives in Lake Ontario. Alewives have been reported in the stomachs of the following fishes caught in Finger Lakes of New York State: lake trout, rainbow trout, cisco, northern pike, smallmouth bass, yellow walleye, and perch. Small alewives, 53–69 mm long, were found in the stomachs of lake whitefish caught in a small lake emptying into the North Channel of Lake Huron (C. A. Lewis, personal communication).

Studies of the parasites of landlocked alewives appear to be rare. Sumner et al. (1913) listed the following parasites of alewives captured in the vicinity of Woods Hole, Massachusetts: Acanthocephala (*Echinorhynchus acus*); cestodes (*Rhynchobothrium imparispine*); trematodes (*Distomum appendiculatum*, *D. bothryophoron*, *D. vitellosum*, and *Monostomum* sp.); and copepods (*Argulus alosae*, *Caligus rapax*, and *Lepeophtheirus edwardsi*).

Rothschild (1966), discussing the probable reasons for mass mortality of alewives, stated that observations of alewives at Interlaken Beach, Cayuga Lake, disclosed a heavy infestation with a fungus that he presumed to be *Saprolegnia*.

Hoffman (1967) listed larval forms of trematodes *Diplostomulum flexicaudum* and *Neascus* sp.; the immature adult form of the nematode *Contracaecum* sp. and of the acanthocephalan *Leptorhynchoides thecatus*; molluscan Glochidia, and the crustacean *Argulus alosae*, from the alewife in North American waters.

Relation to man In the Great Lakes the alewife has long been considered a nuisance. In some instances live alewives are so abundant inshore that they may clog industrial and municipal intake pipes as in Chicago in 1967. They are particularly obnoxious, however, during the periods of mass die-offs. When in shallow water during the spring and summer months, alewives often die in large numbers, and dead and dying fish may drift in or be washed up on shore, littering beaches and harbours, a common occurrence in Lake Ontario's Toronto-Hamilton region (*see* accompanying photograph). Such mortalities can be severe enough to constitute a very real health hazard to adjacent communities.

Many theories have been advanced to account for these die-offs or mortalities. Graham's studies were the most comprehensive and pertinent and his conclusions concerning mortalities in Lake Ontario were as follows: "Briefly, the annual mortality of the alewife appears due to the alewife's inability to acclimate rapidly to rising or fluctuating temperatures. Early incidences of the mortality follow when the alewife invades the warm spring shoal waters while acclimated to the cold temperatures of the lake bottom. Later and more extensive incidences, although not fully explained here, are also probably associated with lethal temperatures." An exhausted thyroid was suggested by Hoar (1952) as the trigger mechanism of the summer mortalities.

The Great Lakes populations of alewives have not been seriously exploited by commer-

cial fisheries, largely because these landlocked fish are small, thin, and bony. However, in recent years they have been used increasingly in the preparation of pet food and also for fish meal.

The rapid growth of coho salmon, *Oncorhynchus kisutch*, planted in Lake Michigan waters in 1966 has been attributed, in part, to the abundant supply of alewives upon which they feed; but alewives have been shown to accumulate, in their tissues, particularly in their body fat, the chlorinated hydrocarbon dichloro-diphenyl-trichloroethane, commonly known as DDT, which they pick up from eating planktonic organisms. Because of the large quantities of alewives eaten by each individual coho, and because a relatively high proportion of DDT is retained by the ingesting organism, DDT levels in the tissues of cohos became alarmingly high, exceeding the tolerance levels permitted by health authorities.

The introduction of the alewife to freshwater lakes to serve as a forage fish was described and discussed by Vincent (1960) but experience suggests that considerable advance study be given to proposed introductions.

In its native environment along the Atlantic coast, the alewife is large and meaty and considered desirable as food for human consumption, as well as a forage fish for large predators.

In the Maritime Provinces commercial fisheries are conducted in the Saint John and Miramichi rivers in New Brunswick, and the Margaree, Mersey, Tusket, Gaspereau, and Shubenacadie rivers in Nova Scotia. In 1970, approximately 7.2 million pounds of alewives were landed, with a landed value of $156,000. Most were used in the pet food industry, a small quantity were used fresh and smoked (Gillespie 1967). The flesh is sweet but bony.

Nomenclature

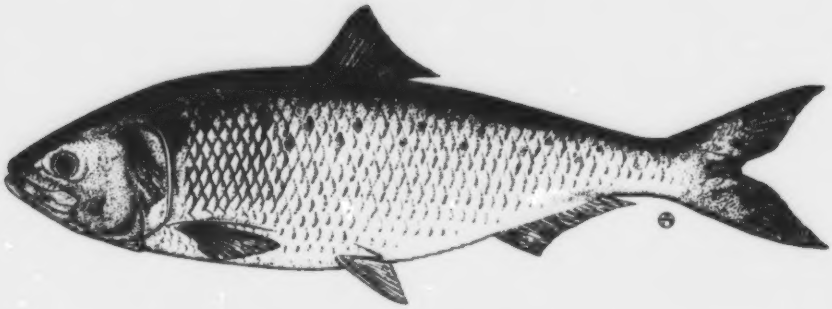
Clupea pseudo harengus Wilson — *In* Rees' New Cyclopedia, 9 (no page), ca. 1811 (type locality probably Philadelphia)
Alosa vernalis Mitch. — Richardson 1836: 229
Alosa tyrannus — Perley 1852: 209
Clupea vernalis Mitchill — Cox 1896b: 66
Pomolobus pseudo-harengus Wilson — Hubbs 1926: 10
Pomolobus pseudoharengus (Wilson) — Jordan, Evermann, and Clark 1930: 42
Alosa pseudoharengus (Wilson) — Bailey et al. 1970: 15

Etymology *Alosa* — Saxon "allis," old name of the European shad *Alosa alosa; pseudoharengus* — false; herring.

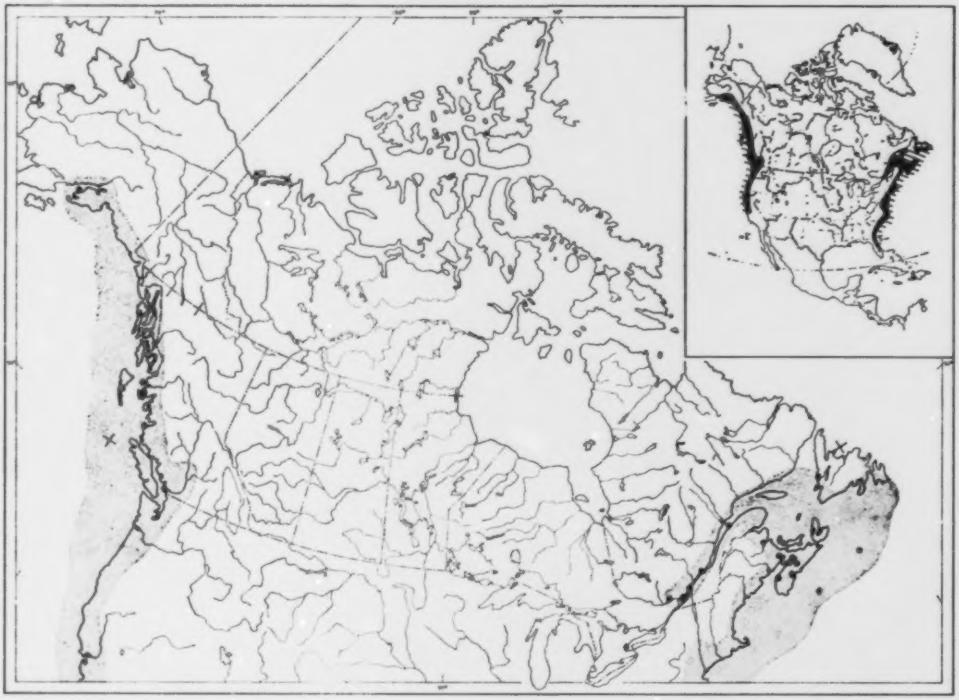
Common names Alewife, mulhaden, gray herring, blear-eyed herring, spring herring, golden shad, seth, green shad, skipjack, bang, racer, kyak or kiack, gaspereau, ellwife, branch herring, sawbelly, wall-eyed herring, big-eyed herring, glut herring, grayback. French common name: *gaspareau.*

AMERICAN SHAD

Alosa sapidissima (Wilson)



Description Body rather elongate, average length 15 inches (381 mm), strongly compressed laterally, and rather deep, its depth 17.2–19.4% of total length. Head broadly triangular, 22.7–24.0% of total length; gill membranes entirely free from isthmus; eye moderate, adipose eyelid well developed, diameter of eye 27.3–32.0% of head length; snout moderate, its length 26.9–32.0% of head length; interorbital width 18.6–21.6% of head length; anterior end of lower jaw not excessively thick or heavy, somewhat pointed, and fitting easily into a deep notch in upper jaw so that jaws about equal when mouth closed; maxillary extending to posterior margin of eye; teeth small, weak, and few in number on premaxillary and mandible. Gill rakers on lower limb only



59–73. Branchiostegal rays 7,7 (rarely 7,6). Fins: dorsal 1, its height moderate, base short, 11.3–12.9% of total length, total rays 15–19, usually 17 or 18; caudal distinctly forked; anal 1, base length greater than dorsal base, 12.8–14.2% of total length and height shorter than dorsal, rays 18–24, usually 20–22; pelvics abdominal, small, length 9.2–10.2% of total length, rays 9; pectorals low on sides, length 13.8–14.6% of total length, rays 14–18, most often 16. Scales large, crenulate on posterior margin, deciduous. Lateral line not developed but scales in about 50–55 rows, midlaterally; ventral scutes well developed, pre-pelvic scutes 19–23, usually 20–22, post-pelvic scutes 12–19, usually 15–17. Pyloric caeca numerous and usually clustered on right side. Vertebrae 53–59, usually 55–58. (Meristic data from Leim 1924.)

Colour The overall colour of the American shad is silvery, with a blue or blue-green metallic luster on the back. The sides are bright silvery. There is a large black spot on the shoulder close behind the rear edge of the gill cover, followed by several (4–27) smaller dark spots. Sometimes a second row of spots is present below the first, varying from 1 to 16 spots and, rarely, a third row of 2–9 spots may occur below the second row.

Distribution The American shad is an anadromous species, inhabiting the waters on the Atlantic coast from Newfoundland southward to Florida. It is most abundant from Connecticut to North Carolina. On the Pacific coast, where the shad was introduced into the Sacramento and Columbia rivers in 1871, it has become established from southern California to Cook Inlet, Alaska, and the Kamchatka Peninsula on the Asiatic side. It was first taken in British Columbia waters in 1876 near Vancouver Island and is now caught in the Fraser River in increasing numbers (Clemens and Wilby 1961).

In Canada the shad was reported in June 1932 from Bay Bulls, Nfld.; however, the first fully documented record was of a female 18.9 inches (480 mm) long, caught in a salmon net in Wild Cove, Bay of Islands, Nfld., in 1963. This appears to be the northernmost limit of range (Scott and Crossman 1964). In 1966 Hodder reported the capture of two specimens, one from St. John's and one from St. Phillips on the east coast of Newfoundland. Halkett (1913) indicated that the American shad occurred in Labrador but we have been unable to verify the information, and Backus (1957) did not record its occurrence there.

It is found in the Gulf of St. Lawrence and, in spring, ascends freshwater streams of the Maritime Provinces and Quebec. Leim (1924) reviewed the distribution of shad in Canadian Atlantic waters in considerable detail. He noted they were found mainly near the mouths of four rivers tributary to the Bay of Fundy — the Saint John, Petitcodiac, Shubenacadie, and Annapolis rivers. It is to be expected that deteriorating environmental conditions, particularly pollution, would render these rivers, especially the Saint John, much less suitable for spawning shad than in former years. Leim noted that runs in streams on the outer coast of Nova Scotia and Prince Edward Island, and in Northumberland Strait, were irregular and unimportant, but those in the Miramichi were regular and valuable. Runs also occurred in rivers tributary to the St. Lawrence, including the Ottawa River. There was an annual migration up the Ottawa River, at least to Point Fortune on the southwest shore at the Ontario–Quebec border. Presumably the fish were unable to ascend above this point after the erection of the dam in 1882. In a paper dealing with the fishes of the Ottawa River written in 1939, J. R. Dymond documented 19th century and later accounts of the movements of shad in the Ottawa River. It is of special interest to note that shad were once abundant at Chute à Blondeau, four miles above Point Fortune, but H. B. Small (1883), writing about shad, noted ". . . the beds of sawdust which extend everywhere above Carillon would hardly invite these delicate fish to pursue their wanderings any farther." Carillon is opposite Point Fortune on the Ottawa River. This region is probably even less attractive in 1973.

Introductions of American shad have generally proved unsuccessful, with the exception of those made in Pacific coastal rivers noted above. Attempts to introduce the species into Lake Ontario waters failed, as did efforts in the Mississippi River drainage, peninsular Florida, Colorado, and Great Salt Lake.

Biology The anadromous American shad ascends freshwater rivers and streams in the spring to spawn, the precise time depending upon the water temperature. Normally the American shad does not ascend the rivers as far as the alewife, but tagging has revealed that some do travel great distances; for example, from Virginia to New Brunswick's Miramichi estuary in the same year. The erection of dams and other obstructions in streams undoubtedly prevents or seriously impedes migration in many areas. Observations indicate that, unlike the alewife, spawning takes place rarely, if ever, in lakes. In Canadian waters spawning occurs in May, June, or even as late as July.

A detailed account of the life history of the shad was prepared by Leim (1924), the source for much of the following information. The males arrive on the spawning grounds first, soon followed by the females. Spawning does not commence until the water temperature reaches 53.6° F (12° C) and will continue as long as temperature does not drop significantly below this point. Peak of spawning run occurs at temperatures of about 65° F (18.3° C). During the spawning act, the female is accompanied by several males; the spawning fish swim vigorously close to the surface, leaving a visible wake. Leim noted that spawning took place in the evening after sundown and continued until midnight and even later. The eggs are released in the open water where they are fertilized by the males. It is often stated that female shad may produce from 20,000 to 150,000 eggs, depending upon her size, but the largest females do not necessarily produce the most eggs. In a study of shad fecundity in the St. Lawrence River near Ile Verte, Que., Roy (1969) reported a range of 58,534–390,633 eggs per female, with an average of 125,166 for 48 fish. The female with the largest number of eggs (390,633) measured 21.5 inches (546 mm) and weighed 6.25 pounds, another measuring 21.3 inches (541 mm) contained only 73,095 eggs. Davis (1957) estimated the ova production from five shad in each of six Atlantic coast rivers, from the Hudson River in New York to the St. Johns River in Florida, and results ranged from a low of 209,000 eggs from a 19.5-inch (495-mm) Hudson River shad, to a maximum of 616,000 from a 16.6-inch (421-mm) St. Johns River shad. Fertilized eggs are 2.5–3.5 mm in diameter and are transparent, pale pink, or amber. Only slightly heavier than the water and nonadhesive, they settle singly and are carried along by the current. Hatching takes place in 8–12 days at temperatures of 51.8°–59.0° F (11°–15° C). Leim (1924) provided evidence indicating that eggs hatch more successfully in slightly brackish water (7.5 ppm at 53.6° F (12° C) to 15 ppm at 62.6° F (17° C)).

Important work on shad biology is being done by W. C. Leggett, McGill University.

After spawning the spent fish begin to drop back to salt water and vanish until the next spawning season. Little is known of their life in the sea but, like the alewife, they are schooling fishes.

Cheek (1968) stated that shad that spawn in coastal streams of the South Atlantic states die after spawning. The reason for the mortality is unknown but he noted that the number of shad that survived after their first spawning, increased northward. Indications are that shad spawn more than once, and have been known to spawn as many as five times.

The larvae, about 9–10 mm long when hatched and very slender, spend their first summer in the river. They drift down to brackish water and by autumn, when 2–3 inches (51–76 mm) long, all have left fresh water and entered the sea. They remain in the sea until they are mature. Leim (1924) noted that Bay of Fundy shad may attain lengths of 3–6 inches (75–175 mm) at the end of the first growing season. Two-year-old fish average about 9.2 inches (230 mm), 3-year-olds about 11.8 inches (300 mm), and 4-year-olds about 16.9 inches (430 mm). For precise details *see* Leim (1924). Although a few spawn at age 4, most are 5 years old and 18–19 inches long when they commence spawning activity. The oldest shad in the Bay of Fundy are 8 or 9 years old; the largest shad in the Gulf of St. Lawrence are somewhat older. Cating (1953) reported shad 11 years old and 23 inches (584 mm) long from United States waters. Mansueti and Hardy (1967) illustrated and described larval stages in the Chesapeake Bay region.

American shad are plankton feeders. Larvae and young American shad eat copepods and related crustaceans and insect larvae (chironomids) while they are in fresh water. When in the sea, the diet consists principally of copepods and mysids, supplemented by small quantities of other planktonic crustaceans and some small fishes. Migrating fish eat little, if anything, prior to spawning, but commence feeding during downstream postspawning migration.

American shad are preyed upon by seals but adults seem to have few enemies, except man. Young shad may fall prey to a variety of predators in fresh waters but Leim (1924) could not demonstrate predation by either eels or striped bass in the Shubenacadie River, N.S.

Shad do not appear to be severely infested by parasites. Leim (1924) noted that of 40 specimens examined in 1922, only two contained parasites. Adult shad at Scotsman Bay, N.S., were found to contain three kinds of parasites — distomes, nematodes, and Acanthocephala. Sumner et al. (1913) summarized the findings of Linton and Wilson, working with shad in the Woods Hole, Mass., vicinity, as follows: Acanthocephala (Linton), *Echinorhynchus acus.*; nematodes (Linton) — *Ascaris adunca*, *Ascaris* sp. (immature); copepods (C. B. Wilson) — *Caligus rapax*. *Lernallnicus radiatus* was also added to the list.

Hoffman (1967) listed only two parasites from the shad in North American waters: the larval form of the trematode *Clinostomum marginatum*, and the crustacean, *Argulus canadensis*.

Relation to man American shad are caught commercially in weirs, traps, and gillnets while on their spawning migrations in rivers and estuaries in Nova Scotia, New Brunswick, Quebec, and the coastal United States. A few small sea fisheries exist. The maximum Canadian catch in 1875 was 3⅓ million pounds, and the United States took 50 million pounds in 1896. Although catches have declined since 1900, the Canadian catch increased in the 1950's approximating the 1875 level, but has since declined again. Accurate landing records for American shad in recent years are unavailable, since the catch for the species is grouped under the category "shads" in the statistics.

Shad is esteemed as a game fish in many parts of the eastern United States where it is caught by fly-fishing and trolling, but it is seldom regarded as a game fish in Canadian waters.

American shad is marketed fresh and salted. The flesh is white and flaky and, when properly prepared, the caviar made from the roe is highly esteemed. Shad liver oil contains from 500 to 800 U.S.P. of Vitamin A, and from 50 to 100 I.U. of Vitamin D per gram, and thus is less rich in vitamins than oil from cod or haddock livers.

Nomenclature

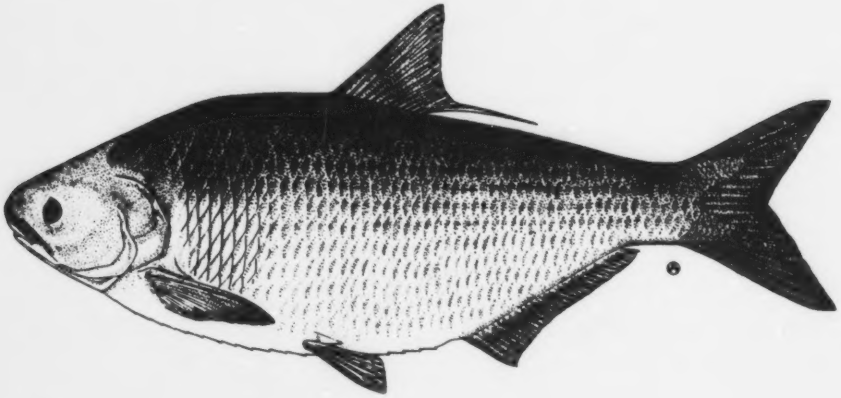
Clupea sapidissima Wilson — *In* Rees' New Cyclopedia 9 (no page), ca. 1811 (type locality probably Philadelphia)
Alosa sapidissima Wilson — Perley 1852: 206
Alosa sapidissima (Wilson) — Bailey et al. 1970: 15

Etymology *Alosa* — Saxon "allis," old name of the European shad *Alosa alosa; sapidissima* — most delicious.

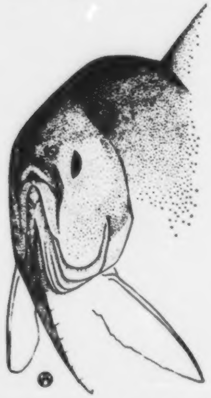
Common names American shad, shad, alose, common shad, Atlantic shad, North River shad, Potomac shad, Connecticut River shad, Delaware shad, Susquehanna shad, white shad. French common name: *alose savoureuse*.

GIZZARD SHAD

Dorosoma cepedianum (Lesueur)



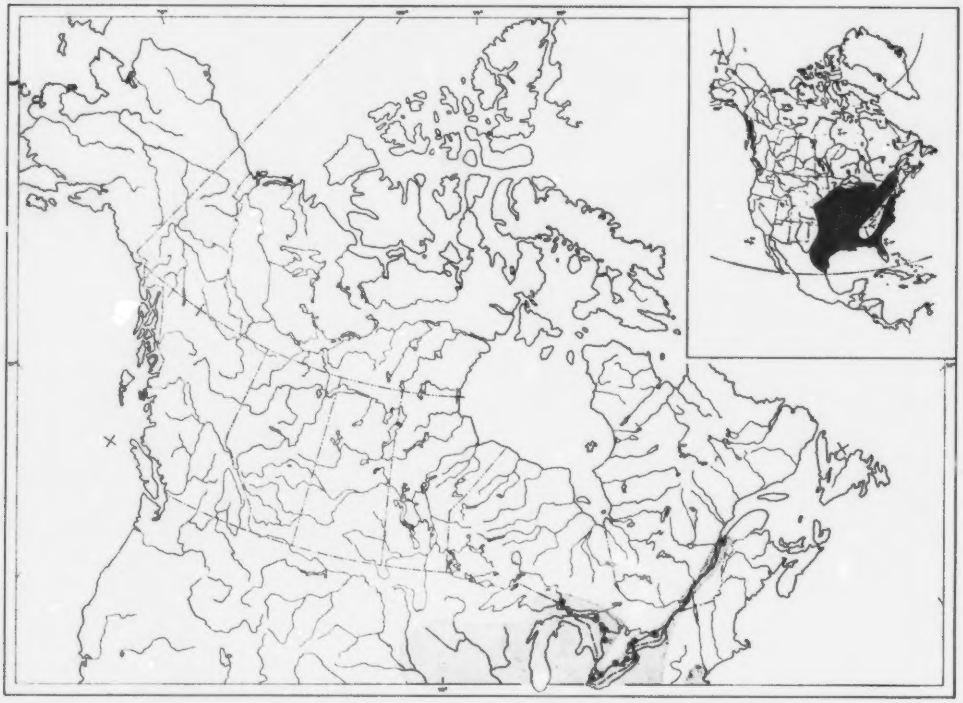
Description Body strongly compressed laterally and deep, 23.5–29.3% of total length, average length 10 inches (254 mm).



Head bluntly rounded anteriorly, its length 22.1–26.4% of total length; eye moderate in size, its diameter 20.2–26.4% of head length; adipose eyelid usually well developed and obvious; snout rounded, 16.9–24.2% of head length, and overhanging inferior mouth; interorbital width 21.2–26.8% of head length; maxillary terminating about anterior margin of eye; a few minute teeth on young but these are soon lost. Gill rakers numerous, long and slender, number increases with size, varying from 100 to about 400. Branchiostegal rays 6,6. Fins: dorsal 1, base short, height of anterior rays 15.3–17.2% of total length, last ray greatly prolonged on young adults, short or nonexistent on young, shorter on old adults, total rays 10–13, usually 10–12; caudal distinctly forked; anal 1, rays short, base long, 20.0–22.7% of total length, rays 27–34; pelvics abdominal, length 9.5–10.9% of total length, rays 8–10; pectorals longer than pelvics, length 15.0–16.8% of total length, rays 16 or 17. Scales large, silvery, 52–70 scales in a lateral series; lateral line not developed; ventral scutes well developed, pre-pelvic scutes 18 or 19 and post-pelvic scutes 12 or 13. Pyloric caeca numerous, and a thick-walled stomach ("gizzard"). Vertebra 47–49.

Colour The body of the gizzard shad is silvery blue on the back and upper sides, shading to silvery on the lower sides and milky white below. The scales often reflect a golden or brassy tinge. There is a large, round, dark spot on the "shoulder" (behind the opercle and above the pectoral fin base) prominent on fish up to 6–8 inches (152–203 mm) long.

Systematic notes Three subspecies have been described, *D. c. cepedianum*, *D. c.*



heterurum, and *D. c. exile*. Miller (1960) suggested that the accepted bases for these are not valid. He presented comprehensive morphometric and meristic values for the species throughout its North American range, indicating in many instances a wider range of values for many characters than are given above for Canadian populations.

Distribution An inhabitant of eastern North America, the gizzard shad occurs in the waters of the Atlantic slope from about 40°N (lower New York Harbour), south to the Gulf coast of the United States, and to the basin of the Rio Pánuco in eastern Mexico (Miller 1960). Inland, the species ranges from southeastern South Dakota and central Minnesota, the Great Lakes drainage, the most southern part of New York, and throughout the Mississippi valley.

The occurrence of the gizzard shad in many areas is believed to be due to its migration through canals and waterways. Presence in the northern region of Cayuga Lake, N.Y. is perhaps due to the Erie Barge Canal, and its first appearance in Lake Michigan in 1953 (Miller 1957) is attributed to entrance through the Chicago River Canal.

In Canada the species was reported erroneously from New Brunswick, but a correction was made by Scott and Crossman (1959). Its occurrence in the St. Lawrence River is rare. Vladykov (1945) reported six specimens taken in the St. Lawrence River near Quebec City in 1945. It is also rare in Lake Ontario but is a common species in Lake Erie. There is considerable speculation as to its origin in Lake Erie. Some authors believe it found its way through various canal connections from the Mississippi drainage (Kirtland 1850). Gerking (1945) suggested it might have migrated into the glacial Great Lakes from the Mississippi drainage during the Lake Maumee outlet stage, and Trautman (1957) thought this species was present in the lake before the canals were constructed. Miller (1957), discussing the origin of the gizzard shad in Lake Erie, stated that the question of whether the shad is native to Lake Erie cannot be solved conclusively. It also occurs in lakes St. Clair and Huron and in Georgian Bay. Previously unrecorded from Lake Superior, its range has recently been extended into this lake when a 1½-pound specimen was caught in a commercial gillnet in Batchawana Bay in 1961.

It is absent from the waters of western North America.

Biology There are no published observations on spawning of gizzard shad in Canadian waters, which is perhaps not surprising since the species is on the northern limit of its range in the Great Lakes and St. Lawrence River. In general, spawning occurs in fresh water, in the spring or early summer, on a rising temperature in our area, but elsewhere Miller (1960) noted that spawning may occur from mid-March to mid-August in sloughs, ponds, lakes, and large rivers. The same author observed, "A group of males and females swimming near the surface begin to roll and tumble about each other in a mass, the eggs and sperm being ejected during this activity. The sticky eggs slowly sink to the bottom or drift with the current, readily becoming attached to any object they may contact." Direct observation in Ohio waters suggests that spawning occurs during the daytime but Bodola (1966) was unable to confirm this during a detailed study of the species in western Lake Erie. He found only one spawning site, a sand, gravel, and boulder bar in 2–4 feet of water where spawning apparently occurred in 1955 between early June and early July at temperatures of 63°–73° F (17.2°–22.8° C). Temperature is an important factor in the initiation and continuation of spawning. Fish return to deeper water after spawning.

On extrusion, gizzard shad eggs are small, about 0.75 mm in diameter, adhesive, each containing one large, clear, oil globule and one or two smaller ones. There is apparently considerable variation in the number of eggs per individual. Data presented by Bodola, although based on small samples, indicated maximum egg production by age 2 fish, counts ranging from about 211,380 to 543,910 eggs, and averaging about 379,000. Egg production declined in age 3 and older fish and was significantly lower in precocious age 1 females.

The embryology of gizzard shad was studied by Warner (1941) but reported only in abstract. Material and figures from Warner's work were presented by Miller (1960) who noted that eggs hatch in 95 hours at 62° F (16.7° C) or in about 36 hours at 80° F (26.7° C). Young fish reared by Bodola, who gave hatching time as 36 hours to 1 week, depending on temperature, were 5.2 mm long in 4 days.

According to data from Bodola (1966), the average standard length in mm of five age-groups for Lake Erie males and females was:

Age	Avg SL (*mm*)	
	Male	Female
1	141	140
2	273	285
3	313	335
4	343	366
5	349	390

Notice that after the first year, females are consistently longer than males of the same age.

The oldest shad caught in Lake Erie during the same study were 3 age 6 fish (2 males, 1 female), although fish to age 10 have been reported from more southern waters. Mansueti and Hardy (1967) illustrated and described larval stages in the Chesapeake Bay region.

When the gizzard shad commences to feed, about the fifth day after hatching, it is slender in shape, with a straight, tubelike, alimentary tract or gut. At this time it feeds on minute animal plankton, especially protozoans and entomostracans. Young, up to 22 mm long, have been found to contain, almost entirely, water fleas (*Bosmina*), copepods, and a few ostracods. As the gizzard shad grows, its shape begins to change to the adult form (after the 20-mm stage), gill rakers increase and lengthen, the pyloric caeca begin to develop (at about 27.5 mm), the gizzard develops, the gut becomes convoluted and long, and the food changes from animal plankton to minute algae. The anatomy and biology of the digestive system have been described in detail by Wier and Churchill (1946).

Fully developed gizzard shad are herbivorous, feeding on the bottom on microscopic plants or phytoplankton and algae, which they are able to digest and assimilate because of their specialized alimentary canal. Although not unique in this respect (*see* Cyprinidae) they are one of the few species among our native fishes that can exist almost solely on vegetative material, thus forming a significant link with the economically important predators. Stomachs of adults often contain large quantities of mud, but this is believed to be ingested accidentally. Bodola (1966) observed that the species appeared to eat little in winter and early spring. Feeding habits of gizzard shad in Ohio waters have been described in detail by Tiffany (1921).

Young gizzard shad have many enemies and, indeed, form an important source of forage for most game and commercial species present. However, only large predators, such as northern pike, muskellunge, channel catfish, and large walleye could eat adult gizzard shad and there are few records of such predation in Ontario waters.

Miller (1960) noted that this species was generally free from parasites. The young may often be infested with a myxosporidian resulting in large white cysts in the body cavity. Smith (1949) found the copepod parasite *Ergasilus lanceolatus* in gizzard shad in Cumberland River, Ky. Hunter (1930) reported the cestode *Glaridacris confusus* in the intestine of this species in Oneida Lake, N.Y. (*see* Van Cleave and Mueller 1934, p. 262).

Bangham and Hunter (1939) examined five specimens of gizzard shad in Lake Erie during their study. All were taken from the western end of the lake. Only one, a young fish, contained a parasite — a nematode, *Agamonema* sp. Hoffman (1967) listed Protozoa (1), Trematoda (8), Cestoda (2), Acanthocephala (3), and Crustacea (3) from the species in the fresh waters of North America.

Relation to man The young gizzard shad is an important forage fish for game and predaceous fishes before its rapid growth makes it a less utilizable food item. Kutkuhn (1958) stated that studies in the midwestern United States showed that ". . . the species often passes out of range of effective utilization by the middle of its second year of life." Since the gizzard shad is not eaten by many predators after it has attained a large size, breeding stocks are perpetuated and can, when in sufficient numbers, compete with the predators. However, the gizzard shad is a highly efficient species in terms of energy exchange and, although not widely utilized in Canada as a pond culture forage species, its potential should be explored, especially since heated effluents from various types of power stations will produce the kind of habitat suitable for this species. Its role as a forage species was reviewed in detail by Miller (1960).

In some areas where the species is abundant, the gizzard shad creates a problem, and fish management programs have been instituted (Bodola 1966). In Lake Erie their value as a forage fish is outweighed by the nuisance created when heavy mortality occurs and by the inconvenience caused to fishermen in whose nets they become entangled. They may be particularly abundant in the shallow inshore waters of harbours and river mouths of Lake Erie's north shore in the fall of the year.

The gizzard shad is used for fertilizer and as food for cattle and hogs. Miller (1960) reported that a factory for the making of guano from the species existed in Florida in 1874.

It is not an entirely satisfactory bait fish since the young are fragile and die quickly. The flesh is soft and generally considered to be unappetizing and bony, making it an undesirable item for human consumption.

Nomenclature

Megalops Cepediana — LeSueur 1818a: 361 (type locality Delaware and Chesapeake bays)
Dorosoma cepedianum — Nash 1908: 52
Dorosoma cepedianum (LeSueur) — Hubbs and Lagler 1941: 27

Etymology *Dorosoma* — lance; body (in allusion to form of body in the young); *cepedianum* — named for Comte de La Cépède (1756–1825), now spelled Lacépède, the author of Histoire Naturelle des Poissons.

Common names Gizzard shad, hickory shad, mud shad, lake shad, shad, sawbelly, eastern gizzard shad. French common name: *alose à gésier*.

Suggested Reading – Clupeidae

BERRY, F. H. 1964. Review and emendation of: family Clupeidae by S. F. Hildebrand. Copeia 1964: 720–730.

BODOLA, A. 1966. Life history of the gizzard shad, *Dorosoma cepedianum* (LeSueur), in western Lake Erie. U.S. Fish Wildl. Serv. Fish. Bull. 65(2): 391–425.

CHEEK, R. P. 1968. The American shad. U.S. Fish Wildl. Serv. Fish. Leafl. 614: 13 p.

GRAHAM, J. J. 1956. Observations on the alewife, *Pomolobus pseudoharengus* (Wilson), in fresh water. Univ. Toronto Stud., Biol. Ser. 62, Publ. Ont. Fish. Res. Lab. 74: 43 p.

HILDEBRAND, S. F. 1963. Family Clupeidae, p. 257–454. *In* Fishes of the western North Atlantic. Mem. Sears Found. Mar. Res. 1(3): 630 p.

LAGLER, K. F., and V. C. APPLEGATE. 1942. Age and growth of the gizzard shad, *Dorosoma cepedianum* (LeSueur), with a discussion of its value as a buffer and as forage of game fishes. Invest. Ind. Lakes Streams, Ind. Dep. Conserv. 2: 99–110.

LEGGETT, W. C., and R. R. WHITNEY. 1972. Water temperature and the migrations of American shad. Fish. Bull. 70(3): 659–670.

LEIM, A. H. 1924. The life history of the shad (*Alosa sapidissima* (Wilson)) with special reference to the factors limiting its abundance. Contrib. Can. Biol. n.s. 2(1): 163–284.

MILLER, R. R. 1950. A review of the American clupeid fishes of the genus *Dorosoma*. Proc. U.S. Nat. Mus. 100(3267): 387–410.

1957. Origin and dispersal of the alewife, *Alosa pseudoharengus*, and the gizzard shad, *Dorosoma cepedianum*, in the Great Lakes. Trans. Amer. Fish. Soc. 86: 97–111.

1960. Systematics and biology of the gizzard shad (*Dorosoma cepedianum*) and related fishes. U.S. Fish Wildl. Serv. Fish. Bull. 173, vol. 60: 371–392.

PRITCHARD, A. L. 1929. The alewife (*Pomolobus pseudoharengus*) in Lake Ontario. Univ. Toronto Stud., Publ. Ont. Fish. Res. Lab. 38: 37–54.

ROY, J. M. 1969. The American shad and the alewife. Fish. Dep. Que. Fishes of Quebec Album 8: 24 p.

SMITH, S. H. 1968. That little pest — the alewife. Limnos 1(2): 12–20.

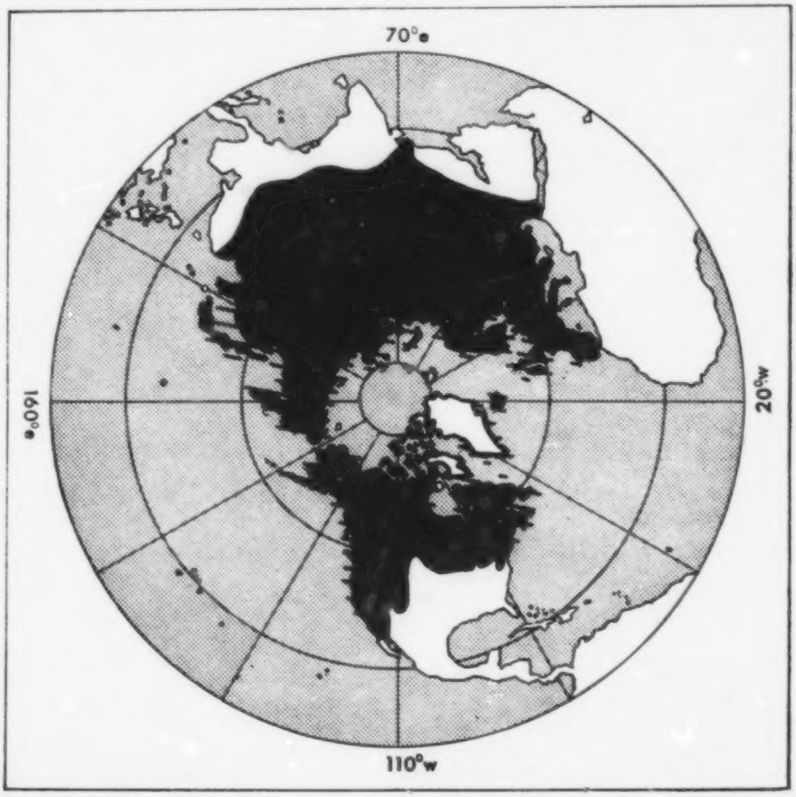
VLADYKOV, V. D. 1956. Distant recaptures of shad (*Alosa sapidissima*) tagged in Quebec. Natur. Can. 83(10): 235–250.

SALMON FAMILY — Salmonidae

The salmonids are medium- to large-sized terete-bodied fishes, variable in shape and appearance, but, in general, less laterally compressed than the herrings. The mouth may be large and well toothed or small and almost toothless. Scales cycloid, confined to body, not on head, circuli formed in more or less concentric rings, lateral line present; pelvic, and sometimes pectoral, axillary scales present. Pyloric caeca well developed and numerous. Vertebrae, 3 upturned in caudal complex.

The family Salmonidae is composed of freshwater or anadromous fishes, ranging widely in the waters of the northern hemisphere. It is the dominant family in the northern waters of North America, Europe, and Asia. Some species, notably the arctic char, extend into the high arctic. There are 32 species belonging to this family in Canadian waters.

The family is composed of three subfamilies: Salmoninae (p. 144), Coregoninae (p. 230), and Thymallinae (p. 300).



World Distribution of the Salmonids

KEY TO SPECIES

When in the sea, or in large lakes, body pigmentation is usually masked by heavy, silvery colouration. The characters enumerated in the key will be evident if the specimen is examined carefully.

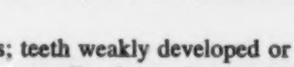
1 Scales small, those in lateral line 115–200; teeth well developed on jaws and vomer; caudal fin usually truncate, occasionally forked; young (6 inches or less) with dark, vertical blotches (parr marks, *see* figures p. 145) on sides (except *O. gorbuscha*). .... SALMONS, TROUTS, CHARS (Salmoninae) 2

Scales large, those in lateral line 100 or less; teeth weakly developed or absent; caudal fin distinctly forked; parr marks usually absent (except *Prosopium* and *Thymallus*); colour generally silvery, silvery green, or silvery blue. .... WHITEFISHES (Coregoninae) and GRAYLING (Thymallinae) 14

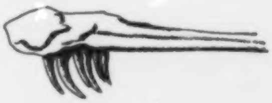
2 Anal rays 13–19 (usually 14–16); body and caudal fin of adults with black spots. .... PACIFIC SALMONS, *Oncorhynchus* spp. 10

Anal rays 7–12 (usually 9–11); body and caudal fin with or without black spots 3

3 Black spots present on head and body (young *S. salar* have red spots between parr marks); scales conspicuous, fewer than 165 in lateral line; pelvic and anal fins without white leading edges; vomer flat with teeth extended backward in 2 rows on shaft 4

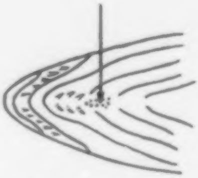


Light spots on body, pink, red, or cream in colour; scales not conspicuous; lower fins with snow-white leading edges; vomer boat-shaped, teeth on the anterior part (head) only, not on shaft 7



4 Caudal fin distinctly marked with radiating rows of black spots; body never with red spots; adipose fin often with black margin; scale rows 120–180 5

Caudal fin usually unspotted, but never with regular rows of black spots; reddish spots sometimes on body; scale rows usually 110–130 6



5 Red or orange-red dash on lower jaw, along inner border of mandible; minute teeth usually present at base of tongue (basibranchial teeth). ...... CUTTHROAT TROUT, *Salmo clarki* (p. 177)

No red colouration present on lower jaw; minute teeth at base of tongue absent. ...... RAINBOW TROUT, KAMLOOPS TROUT, STEELHEAD TROUT, *Salmo gairdneri* (p. 184)

6 Maxillary to below centre of eye in 6-inch fish, seldom far behind eye (except in large males); gill cover with 2 or 3 large spots only; branchiostegals usually 12; dorsal fin rays usually 11; vomerine teeth usually not well developed; small fish have red spots between parr marks; no red on adipose fin. ...... ATLANTIC SALMON, *Salmo salar* (p. 192)

Maxillary to below last half of eye on 5-inch fish, and extending well beyond eye in larger fish; gill cover usually with many spots; branchiostegals usually 10; dorsal fin rays usually 9; vomerine teeth well developed; rust-red spots sometimes on adults and often on margin of adipose fin. ...... BROWN TROUT, *Salmo trutta* (p. 197)

7 Caudal fin deeply forked; dorsal and caudal fins, body and head covered with small, often bean-shaped, light spots; body never brightly coloured with orange or red; parr marks quite irregular and narrow; pyloric caeca over 90. ...... LAKE TROUT, *Salvelinus namaycush* (p. 220)

Caudal fin square (truncate) or slightly forked; body with light-coloured spots of cream, pink, or red; dorsal and caudal fins with dark, wavy lines and marks, or without light spots; pyloric caeca fewer than 75 8

8 Caudal fin square or nearly so; dorsal and caudal fins with distinct, dark, wavy lines or blotches; lower fins with pure white leading edges usually followed by black; back usually with wavy lines (vermiculations); sides with pink or red spots, many of which have blue borders; young with 8–10 regularly arranged parr marks on sides. BROOK TROUT, *Salvelinus fontinalis* (p. 208)

Caudal fin nearly square or slightly forked (may be deeply forked in freshwater populations in eastern Canada) without dark, wavy lines on dorsal and caudal fins; lower fins with pure white leading edges, but not usually followed by black; sides with creamy, pink, or reddish spots, not extending onto fins; parr marks vague or irregular, not well defined 9

9 Spots usually large and less numerous; gill rakers on upper limb of first gill arch 7–13, on lower limb 12–19; pyloric caeca 20–74. ARCTIC CHAR, *Salvelinus alpinus* (p. 201)

Spots round, small, and numerous; gill rakers on upper limb of first gill arch 3–9, on lower limb 8–14; pyloric caeca 13–47. DOLLY VARDEN, *Salvelinus malma* (p. 214)

10 Distinct black spots on back and on caudal fin 11

No distinct black spots on back or caudal fin, but fine black speckling may be present 13

11 Large black spots on back and caudal fin, the largest as large as eye; scales small, 169–229 in first row above lateral line; gill rakers 26–34. PINK SALMON, *Oncorhynchus gorbuscha* (p. 148)

Spots on back and caudal fin small, largest as large as pupil of eye; scales moderate, fewer than 154 in first row above lateral line; gill rakers 19–28 12

12 Small black spots on both lobes of caudal fin; flesh at base of teeth of lower jaw black; pyloric caeca 90–240; gill rakers 20–28. CHINOOK SALMON, *Oncorhynchus tshawytscha* (p. 172)

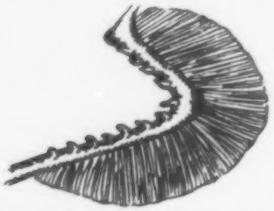
Small black spots, when present on caudal fin, on upper lobe only; flesh at base of teeth of lower jaw pale; pyloric caeca 45–114; gill rakers 19–25. COHO SALMON, *Oncorhynchus kisutch* (p. 158)

13 Gill rakers on first arch 30–40, long, slender, and crowded; pyloric caeca 60–115. .... KOKANEE, SOCKEYE SALMON, *Oncorhynchus nerka* (p. 165)

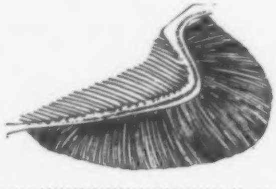
Gill rakers on first arch 19–26, short, stout, and widely spaced; pyloric caeca 140–186. .... CHUM SALMON, *Oncorhynchus keta* (p. 153)

14 Dorsal fin base equal to or longer than head, dorsal fin usually with more than 17 rays, fin larger and sail-like on fishes 8 inches or larger; colour of back bluish or purple; dorsal and pelvic fins sometimes with green or reddish spots. .... ARCTIC GRAYLING, *Thymallus arcticus* (p. 300)

Dorsal fin base shorter than head, dorsal fin rays fewer than 17; dorsal fin not expanded; colour usually silvery, back sometimes black, blue, or green. .... WHITEFISHES (Coregoninae) 15



15 A single small flap of skin between nostrils; snout pinched, rather pointed; mouth inferior; gill rakers stout, short, usually 13–20 but up to 26 in Alberta and British Columbia. .... ROUND WHITEFISHES, *Prosopium* spp. 16



Two small flaps of skin between nostrils; snout not pinched but usually somewhat broad; mouth inferior, overhung by snout, or mouth terminal, lower jaw may be projecting beyond upper; gill rakers generally long and slender, more than 22 (except in *Stenodus*) 18

16 Gill rakers 20–25 (rarely 26); scales around caudal peduncle in 20–23 rows. .... MOUNTAIN WHITEFISH, *Prosopium williamsoni* (p. 291)

Gill rakers 13–20 17

17 Lateral line scales 85–100; scales around caudal peduncle 22–24; pyloric caeca 50–117. .... ROUND WHITEFISH, *Prosopium cylindraceum* (p. 286)

Lateral line scales 55–70; scales around caudal peduncle 18–20; pyloric caeca 15–23. .... PYGMY WHITEFISH, *Prosopium coulteri* (p. 282)

18 Mouth inferior, overhung by snout; premaxillaries retrorse; gill rakers usually fewer than 32 19

Upper and lower jaws nearly equal, or lower jaw projecting; premaxillaries antrorse; gill rakers usually more than 32 (except in *Stenodus*) 21

19 Gill rakers 19–25, short; maxillary short and broad, its length less than twice its width; lower fins thick, opaque, often with bluish cast in life. .... BROAD WHITEFISH, *Coregonus nasus* (p. 278)

Gill rakers 23–33, long; maxillary longer, its length twice or more the width; lower fins not especially thick, translucent, often sprinkled with dark speckles 20

20 Scales in lateral line less than 90 (70–85); mouth inferior, obviously overhung by snout; minute teeth on premaxillaries, palatines and vomer of juveniles only (under 100 mm long). .... LAKE WHITEFISH, *Coregonus clupeaformis* (p. 269)

Scales in lateral line more than 90 (91–100); mouth terminal or nearly so; teeth on premaxillaries, palatines, and vomer, small but present even on adults. .... ATLANTIC WHITEFISH, *Coregonus canadensis* (p. 281)

21 Body shape pikelike; lower jaw distinctly projecting; gill rakers 19–24; scales small, 97–110 in lateral line. .... INCONNU, *Stenodus leucichthys* (p. 295)

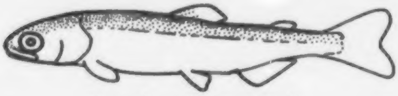
Body shape herring-like; upper and lower jaws equal or nearly so (lower jaw may project slightly); gill rakers more than 32 (commonly 40 or more); scales larger, usually 65–85 (*Coregonus autumnalis*, 86–111). (Numerous keys to the species of the subgenus *Leucichthys* have been attempted. All of them are unsatisfactory because of the excessive phenotypic plasticity of the ciscoes, hence no attempt to separate them is made here. The most variable and wide ranging species is *C. artedii.*) .... Subgenus *Leucichthys*, 11 species (p. 230)

SUBFAMILY SALMONINAE The salmon, trouts, and chars, with orbitosphenoid and suprapreopercular bones, a basibranchial plate; large teeth on maxilla and premaxilla; dermosphenotic bone absent, usually no hypethmoid or epipleurals; and parietals separated at midline by supraoccipital; scales small, rounded; 16 or fewer dorsal fin rays; usually eggs large, no postlarval stage, young usually with parr marks.

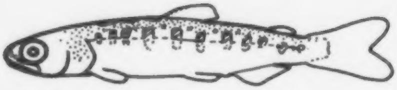
Summary of some meristic characters of Canadian Salmonids

		Principal anal rays	Principal dorsal rays	Branchio-stegal rays	Lateral line scales	Pyloric caeca	Total gill rakers	Vertebrae
Oncorhynchus gorbuscha		13–19	10–15	9–15	147–205	95–224	24–35	63–72
O. keta		13–17	10–14	12–16	124–153	140–249	16–26	59–71
O. kisutch	Gt. Lakes	12–15	10–12	–	112–139	68–79	21–23	–
	anadromous	12–17	9–12	11–15	121–148	45–114	18–25	61–69
O. nerka	kokanee	11–16	11–13	13–14	121–140	50–87	31–44	62–67
	sockeye	13–18	11–16	11–16	120–150	45–115	29–43	56–67
O. tshawytscha		14–19	10–14	13–19	130–165	90–240	16–26	67–75
Salmo clarki		8–12	8–11	10–12	116–230	27–57	14–22	60–64
S. gairdneri		8–12	10–12	9–13	100–150	27–80	16–22	60–64
S. salar		8–11	10–12	11–12	109–121	40–74	15–20	58–61
S. trutta		10–12	12–14	10	120–130	30–60	14–17	56–61
Salvelinus alpinus		8–11	10–12	10–13	123–152	20–74	19–32	60–71
S. fontinalis		9–13	10–14	9–13	110–130	23–55	14–22	58–62
S. malma		9–11	10–12	10–15	105–142	13–47	11–26	57–70
S. namaycush		8–10	8–10	10–14	116–138	93–208	16–26	61–69

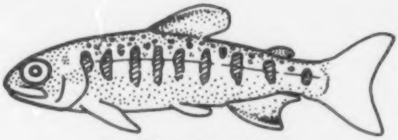
YOUNG TROUTS, CHARS, AND SALMONS
(2–5 INCHES LONG)



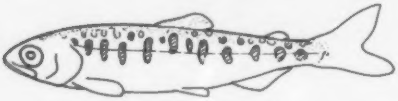
Oncorhynchus gorbuscha



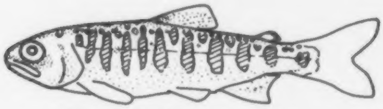
Oncorhynchus keta



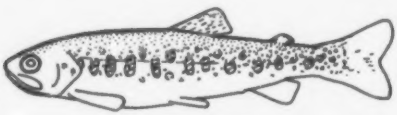
Oncorhynchus kisutch



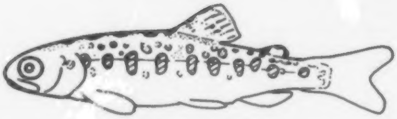
Oncorhynchus nerka



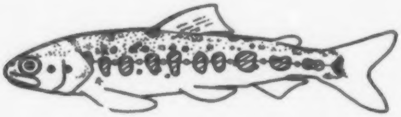
Oncorhynchus tshawytscha



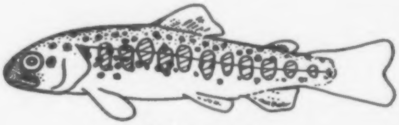
Salmo clarki



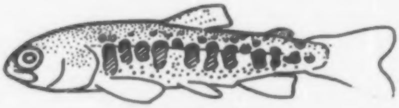
Salmo gairdneri



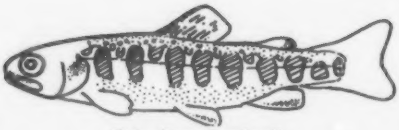
Salmo salar



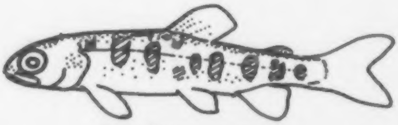
Salmo trutta



Salvelinus alpinus
Salvelinus malma



Salvelinus fontinalis



Salvelinus namaycush

The Pacific Salmons – genus *Oncorhynchus*

Few fishes, except possibly the Atlantic cod and the Atlantic herring, have had as large an impact on man, and of man on them, as have the five Pacific salmons — pink, chum, coho, sockeye, and chinook (two further species, the *biwa* and *masou* are found only in Japan or Russia). In the past, these fishes were often referred to as quinnat in order to distinguish them from the older salmon of the Atlantic. The fact that these rather large marine fishes must return, at differing intervals, to fresh water to spawn has regularly brought millions of fishes to the rivers of the west coast of North America and the east coasts of Japan and the USSR. Before the advent of the white man in North America, this yearly abundance of food facilitated the establishment of permanent settlements of sedentary and highly sophisticated peoples whose food literally came to them.

The written scientific record of these species began with the publications of Steller and Walbaum in the late 1700's. Since that time, the exploitation and value of, and the interest in, these fishes has led to a profusion of literature. As early as 1894 Tarleton Bean published, as Bulletin 12 (1894b) of the United States Fish Commission, a bibliography of such writings. In the late 1800's, primary work on the basic biology of these fishes in the Columbia River was published by Evermann and his co-workers. The obvious value of such fishes was recognized early by people in areas beyond their natural distribution. As early as 1872, the United States Fish Commission had established an egg-taking station on the Sacramento River in California, for the sole purpose of distributing eggs of the various species for introduction elsewhere. By 1930, eggs had been sent to 17 states from Louisiana east, to Canada, to several countries in Europe and South America, to New Zealand, Australia, and Hawaii. In 1966 the Japanese masou (*Oncorhynchus masou* Brevoort) was introduced into Ontario. This is apparently the only known introduction of a species other than those which are native to North America. Only some of these introductions were temporarily or permanently successful.

Commercial exploitation of these species dates at least to 1864 in North America, and Kasahara (1963) attempted to summarize the recorded commercial and sport catches for all species on both sides of the Pacific Ocean. Commercial catch (964.5 million pounds in 1961) has been carried out over the years by means of weirs and huge, anchored, floating traps, gillnets, purse seines, long lines, and trolling with natural and artificial baits. The sports fishery for various species has developed at different times and is of differing intensity.

The ever-increasing exploitation through the 1900's, the extremely high value of the fish as a food resource and as a complex industry employing vast numbers of people, has led to competition between Pacific nations for these fishes and to the eventual establishment of international commissions for the regulation of the fishery. All these pressures required that the various state and federal governments of four competing nations — Canada, the United States, the USSR, and Japan, acquire greater knowledge of these fishes. This included large-scale examination of salmon caught on the high seas and very sophisticated analyses of characteristics ranging from parasites to bones, meristics, and serum, in order to designate the continent of origin or "ownership" of the various stocks. In addition to such practical requirements, there were biological interests in the bodily functions of an animal that, twice in its life, must adjust to a change from salt or fresh water and is able, by visual and olfactory cues, to navigate from the open ocean to the very tributary, often hundreds of miles inland, where its life began.

These various interests have led to a volume of information which cannot be properly summarized for this discussion of all the freshwater fishes of Canada. These species are part of the freshwater fauna only as spawning adults and for a varying period as young. Their external characteristics and details of biology vary from river to river.

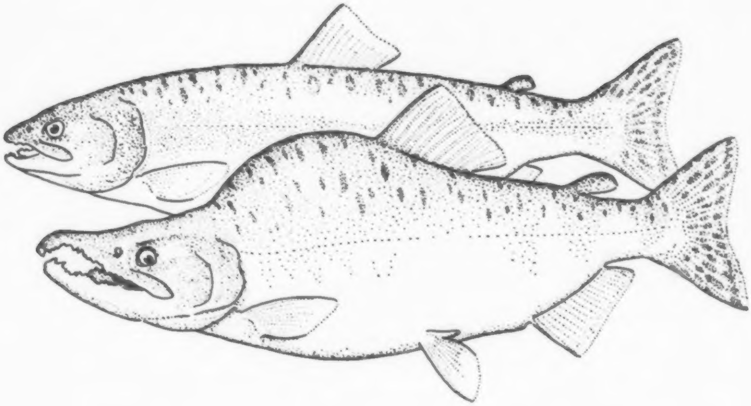
The discussion of each species will deal largely with their freshwater existence and the accounts may seem brief, in view of the importance of these fish, and lacking in detail compared with those of less known but totally freshwater species. We have relied heavily on Clemens and Wilby (1961) and McPhail and Lindsey (1970) for parts of these outlines. The reader interested in greater detail on all or any of these salmon in North America is advised to see the publications of the Department of Fisheries and the Fisheries Research Board of Canada (now the Department of the Environment), the United States Bureau of Commercial Fisheries (now the United States National Marine Fisheries Service), the provincial and state governments of Pacific coast areas, the International Pacific Salmon Fisheries Commission, and the International North Pacific Fisheries Commission. Some specific publications of general interest are as follows: McMurrich (1909) — life history; Dymond and Vladykov (1934) — distribution and relationship; Davidson and Hutchinson (1938) — distribution and environment; Clemens (1953), Foerster (1955) — biology; Wilimovsky and Freihofer (1957) — literature; Rounsefell (1957) — fecundity; Rounsefell (1958) — anadromy; Neave (1958) — origin and speciation; Rounsefell (1962) — morphometrics and relationship; Vladykov (1962) — osteology; Kasahara (1963) — world catch; Bilton et al. (1964) — scale key to species; Margolis et al. (1965) — parasites; Maxfield (1967) — literature 1909–1959; Hart (1973) — general. Hoar and Brett and their students or co-authors have published extensively on the physiology of all species.

The following table shows the comparison of biology and meristics of the Canadian species of Pacific salmon.

	Avg FL (*inches*)	Avg wt (*lb*)	Length of life cycle (*years*)	Gill rakers	Branchiostegal rays	Dorsal fin rays	Anal fin rays	Pelvic fin rays	Pectoral fin rays	Lateral line scales	Pyloric caeca	Vertebrae
Pink	17–19	4	2	24–35	9–15	10–15	13–19	9–11	14–17	147–205	95–224	63–72
Chum	25	11–12.8	3 or 4	16–26	12–16	10–14	13–17	10–11	14–16	124–153	140–249	59–71
Coho												
(anadromous)	18–24	8–12	3 to 5	18–25	11–15	9–12	12–17	9–11	13–16	121–148	45–114	61–69
(freshwater, Ontario)	25	5	3 or 4	21–23	–	10–12	12–15	9–11	12–15	112–139	68–79	–
Sockeye	24–28	5	4	29–43	11–16	11–16	13–18	9–11	11–21	120–150	45–115	56–67
Kokanee	6.3–11	0.65–0.70	2 to 4	31–44	13–14	11–13	11–16	–	–	121–140	50–87	62–67
Chinook	33–36	30–40	4 or 5	16–26	13–19	10–14	14–19	10–11	14–17	130–165	90–240	67–75

PINK SALMON

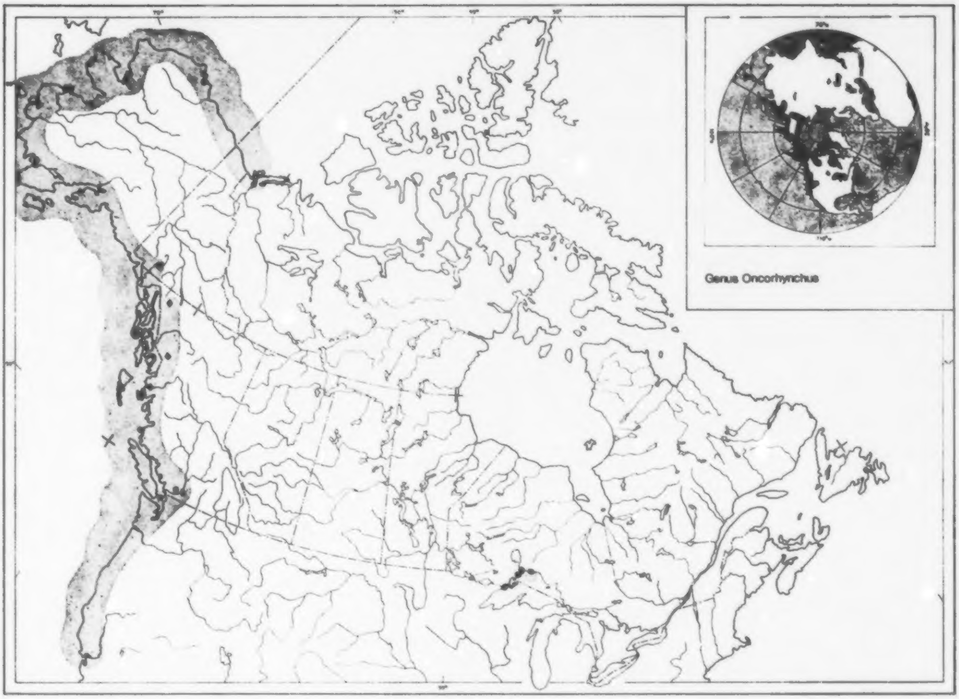
Oncorhynchus gorbuscha (Walbaum)



Description Body fusiform, streamlined, somewhat laterally compressed, usually about 24 inches (610 mm) long as marine adults, but usually not over 18 inches (457 mm) in fresh water in eastern Canada; body depth moderate, deeper in breeding males. Head approximately 20% of total length (longer in breeding males), conical; eye not large, position variable with sex and condition; snout greatly extended, narrow, and turned down at tip in breeding males; mouth terminal, normally very little oblique but greatly deformed in breeding males, with lower jaw enlarged, turned up at tip, mouth unable to close; premaxillaries not protractile; maxillary extending beyond eye; well-developed, sharp teeth on both jaws, head and shaft of vomer, palatines, and tongue, none on basibranchial (= hyoid) bones. Gill rakers of moderate length, 24–35, with 16–21 on lower limb, 8–14 on upper limb. Branchiostegal rays 9–15. Fins: rather large fleshy adipose present; dorsal 1, at centre of body, soft rayed, neither high nor long, square to slightly emarginate, usually 10–15 principal rays; caudal broad, shallowly forked, tips rather pointed; anal with long base, not particularly high, edge square, 13–19 principal rays; pelvics abdominal, not long, axillary process obvious, fin squared to slightly rounded, 9–11 rays; pectorals low, moderately long, tip a rounded point, 14–17 rays. Scales small, cycloid, deeply embedded in spawning fish; lateral line complete, almost straight, 147–205 lateral line scales. Pyloric caeca 95–224. Vertebrae 63–72.

No nuptial tubercles but breeding males with more compressed body and head, prolonged, hooked snout, gaping mouth, enlarged teeth, large hump before dorsal fin, embedded scales and colour change; female changes little except in colour; males permanently in fresh water (Lake Superior) with less spectacular degree of change.

Colour Marine colour: steel blue to blue-green on dorsal surface, sides silver, ventral surface white; back and extreme upper sides with large black spots, adipose fin and both lobes of caudal fin with black spots, those on caudal fin oval, and some as large as the eye. Colour and pattern similar but less brilliant in permanent freshwater populations. Breeding males with head and back darker, sides pale red with brown to olive-green blotches. The young are blue-green on the back, with silvery sides lacking parr marks, and the fins have no black spots.



Distribution As marine adults this salmon occurs in the Pacific and Arctic oceans, the Bering and Okhotsk seas, and the Sea of Japan. Young and spawning adults are found in most tributary rivers of northeast Asia from Peter the Great Bay, north to the Lena River, and in North America from the Sacramento River, Calif., north around Alaska, including the Aleutian Islands, to the delta of the Mackenzie River. They are most abundant in the central part of this range.

In the late 1800's this species was introduced from Maine to Maryland without permanent success. In 1956 pinks collected in the fall of 1955 from the Skeena River, B.C., were introduced in Goose Creek, an Ontario tributary of Hudson Bay. This introduction failed but some of the same brood were released into Lake Superior and have maintained a small population there since that time. In 1958 eggs from Indian, Glendale, and Lakelse rivers of British Columbia were planted in the North Harbour River, St. Mary's Bay, Nfld. By 1967, strays of this stock had spread to Nova Scotia and Labrador, and had penetrated the Gulf of St. Lawrence as far as the Great Watchichou River, Que.

Pink salmon have been introduced in Kola Peninsula of northern Europe and in the Caspian and Black seas. Individuals have been taken as far away as Scotland and Iceland. One stock of pink salmon was maintaining itself in northern Europe in 1968.

Biology Details are from numerous sources and from short summaries by Neave (1966) and Aro and Shepard (1967). Adults migrate from the sea into freshwater rivers from June to September depending on location. They usually move only about 40 miles upstream but may move as much as 300 miles in larger rivers, or may spawn in the lower tidal areas in other rivers. Spawning takes place from mid-July to late October in rivers and tributary streams. Spawning occurs at temperatures as high as 60.8°F (16° C) but spawning of later runs peak at 50° F (10° C). The males are territorial and are aggressive to other males (females are to females also, but to a lesser extent). In this group of fishes it is the female that prepares the nest or redd. This is an excavation in medium-sized gravel and may be as long as 3 feet (915 mm) and as deep as 1½ feet (457 mm), in about 1–2 feet (305–610 mm) of water. The female lies on her side and beats vigorously with her tail to remove silt and light gravel down to a firm gravel bed. The result is a rather deep trough with a raised rim of gravel at the downstream edge. Several males may spawn with a single female in one nest, individual females may build more than one nest, and a single male may spawn with more than one female. The spawning fish settle near the centre of the nest, their mouths gape widely, and sexual products are released during vigorous vibration. Because of the current, eggs may be deposited over the whole length of the excavation. Eggs are covered after spawning by more digging at the upstream edge of the nest which causes gravel to partly fill the nest.

The number of eggs carried by fish entering the spawning area varies with size of the female, the area, and the year. The average has been estimated as 1500–1900 with lows and highs of just over 800 and a little more than 2000. The eggs are large, about 6 mm in diameter, and orange-red in colour. Details of early development were given by Ievleva (1951).

The female usually guards the nest as long as she is able but the spawning adults die in a few days or weeks. Depending on water temperature, hatching occurs from late December to late February. The alevins (young with large yolk) remain in the gravel until the yolk is absorbed in April or early May (rarely late February) when they struggle up out of the nest and become free swimming. They are about 1.3–1.5 inches (33–38 mm) long at this time. Almost immediately after emerging, the fry, which are about 1.25–1.7 inches (30–45 mm) fork length, move downstream at night, often covering 10 miles to the sea in a single night. Those emerging from the higher spawning grounds hide in the gravel by day, become active at night, and are displaced downstream by the current. Other reports suggest they are active, school, and move downstream actively during the day also, particularly when a migration of several days is required. They generally form large schools and are active in the daytime when they reach estuarial water. Young pink salmon may stay in inshore waters for several months before moving to the open sea.

When they first reach the sea they are usually 1.0–1.6 inches (25–40 mm) in length and weigh 0.4 grams. Skud (1955) gave details of length and weight of fry over the migration period in Alaska. In Alaska fingerlings as large as 3.5 inches (89 mm) in length have been taken. It is not known whether they overwinter in fresh water. These large fingerlings may however be chum salmon or chum × pink hybrids.

Pink salmon on the whole live 2 years, although individuals of 3 years of age have been reported. Two-year-old adults, after spending about 18 months in the sea, return to the spawning streams in predictable and highly segregated even-numbered-year and odd-numbered-year runs. Both types of runs or races may use the same stream or one or the other may predominate in a particular river. The Fraser River has an odd-year run and the Queen Charlotte Islands an even-year run. Some streams with a dominant run of one type have a very much smaller off-year run of the other race, which often utilizes different tributaries as spawning grounds. There may be a significant difference in the date of return and in the length and weight of individuals of the two races or of the same race in different spawning rivers. Most of the adults return (home) to the river, and usually to the tributary in which they hatched. There is, however, a degree of wandering, that is, using another stream for spawning. Adults have been taken in spawning streams as much as 400 miles from their original stream. Tagged adults have been captured as much as 1700 miles from the site of tagging. Over the whole area, size of returning adults varies from 2 to 14 pounds. Individuals over 11 pounds are rare, most are 2–7 pounds, and 4 pounds is the overall average. Returning fish are usually 17–19 inches (432–483 mm) in length. When they appear at the river mouths, they are still silvery and the secondary sexual characteristics mentioned in the description develop in the estuary or during the upstream journey.

Pink salmon as young or adults do not remain in fresh water long enough to be said to have a habitat there. The spawning streams are usually small ones with not very coarse gravel, but the main channels of such large rivers as the Fraser and the Yukon are also utilized. Upper lethal temperature and preferred temperature of the young, determined experimentally (Brett 1952) were 75.02° F (23.9° C) and 53.6°–57.2° F (12°–14° C). The extreme low temperature of Hudson Bay may have been responsible for the failure of the pink salmon introduced there. Pink salmon utilize spawning rivers over a wider area than does the sockeye salmon but a very few rivers account for a major part of the British Columbia production. About 78 rivers or 8% of the total number of streams utilized by pink salmon in British Columbia, support 75% of the spawners.

Pink salmon remain in fresh water for such a short time as young that many do not feed at all. Those on longer migrations do take some nymphal and larval insects. Juvenile pinks taken close to shore have fed on copepods, euphausiids, amphipods, ostracods, larvae of decapods, cirripeds, tunicates, and dipterous insects. A detailed study of food of downstream migrants was given by Levanidov and Levanidova (1957). The diet at sea consists of a wide variety of organisms, the most important of which are euphausiids, amphipods, a variety of fishes, squid, copepods, and pteropods. On the Pacific coast, adults do not normally feed after they begin the ascent of the spawning rivers. However, in the Lake Superior population, specimens showing early stages of spawning transformation have been caught in the rivers by anglers using live bait.

The young pink salmon are preyed upon by a variety of stream fishes including cutthroat and rainbow trout, Dolly Varden, coho salmon smolts, squawfish, and various sculpins. Hunter (1959) estimated that in a single stream coho smolts, prickly sculpin, and coastrange sculpin consumed approximately 500,000 pink and chum fry per year. Kingfishers, mergansers, other predaceous birds, and mammals probably account for a small number of fry. Even larvae of stoneflies may prey on eggs and alevins. However, temperature, floods, drought, other water level fluctuation, and too many or too few spawners also control numbers. For details *see* Wickett (1958). Adults at sea are preyed upon by man and marine mammals, and, to a lesser extent, by large fishes. Up to 20% of the pink salmon returning to the Fraser River in 1967 had been attacked by the Pacific lamprey. The Arctic lamprey also parasitizes this species (Williams and Gilhousen 1968).

Details of the parasites of this species (mainly of marine adults) including the newly described trematode *Genolinea oncorhynchi* (Margolis and Adams 1956), will be found in the many papers of Arai, Boyce, and Margolis (and co-authors) in the *Journal of the Fisheries Research Board* and the *Canadian Journal of Zoology*. Hoffman (1967) listed the following parasites of pink salmon in the fresh waters of North America: the protozoan *Cryptobia salmositica*; and trematodes *Genolinea oncorhynchi*, *Hemiurus levinseni* and *Lampritrema nipponicum*, the leech *Piscicola salmostica*, and the crustacean *Lepeophtheirus salmonis*.

The pink salmon is known to hybridize in nature with the chum salmon if not with others. *See* Foerster (1935) and Simon and Noble (1968) for results of artificial hybridization.

Relation to man The pink salmon was apparently less important as a staple food of native people anywhere other species of Pacific salmon were available. Hoar (1951) summarized the fishery from 1917 to 1947. It was also late entering the commercial catch. It and the chum salmon, referred to as "autumn salmon," were considered less desirable, "cheaper species" on the market. Prior to 1911 very few were taken, but the catch jumped drastically because of wartime food requirements and the temporary decrease of the Fraser River catch of other salmon as a result of the Hell's Gate slide. Since that time it has formed an increasing part of the total annual catch in Canada, the U.S., the USSR and Japan. North American catches are lower than those in Asia. The fish are taken mainly by purse seine and gillnets, but a smaller number are taken by troll fishermen. Over the years 1951–1963, the average Canadian catch was 10.1 million fish weighing 48.85 million pounds. In 1968 the catch was 54.83 million pounds with a landed value of nearly 7 million dollars. The bulk of the catch is canned. Only 5% of the catch is prepared as fresh or frozen salmon. The flesh is pink (hence the name) in contrast to the deeper red of the sockeye, and most people today do not look upon it as being so much less desirable than the fancier and more expensive sockeye.

Not until about 1957 was it generally known that the pink salmon in the ocean would take a trolled artificial bait. Since that time it has increased in popularity as a sport fish. Between 1957 and 1961 the estimated annual catch in British Columbia varied from 1000 to 37,000 fish. The 1964 angler catch in British Columbia was analyzed by Tuomi (1964).

The pink salmon has been transplanted to a far less extent than some of the others. The 1956 introduction of about 21,000 fingerlings (1955 year-class) into Lake Superior has never resulted in populations large enough for serious commercial exploitation. The first knowledge of the survival of offspring of that stock was based on captures by anglers in Minnesota in 1959. The first adult pink salmon taken in Ontario was caught in Black Bay, Lake Superior, by a commercial fisherman. Since that time small but increasing numbers have been taken by commercial fishermen and anglers almost every spawning year. The run in 1969 seemed greatly increased. In an Ontario sample of 114 pink salmon taken September 5–27 from seven areas of Lake Superior and its tributaries, the fish varied in length from 13.5 to 18.4 inches (343–467 mm) and were mostly 14–16 inches (356–406 mm). In weight they varied from a spent female 13.9 inches (353 mm) long, that weighed only 8 ounces, to a male 18.4 inches (467 mm) long, that weighed 2 pounds 1 ounce. Most specimens seen have been emaciated and little more than 2 inches (51 mm) thick (side to side).

The introduction into Newfoundland, begun in 1958, has developed a small run in the original river, sporadic reports of the species over the whole east coast of the Island, and a few in Labrador, Nova Scotia, and Quebec. Eggs were last introduced in 1966 and there were spawning runs in 1969 and 1970 of adults that had developed from natural egg deposition. Newfoundland commercial fishermen took 800 pink salmon in 1969. These are apparently marketed as Atlantic salmon at the price charged for that species. Only a few pink salmon are taken each year by Newfoundland anglers.

Nomenclature

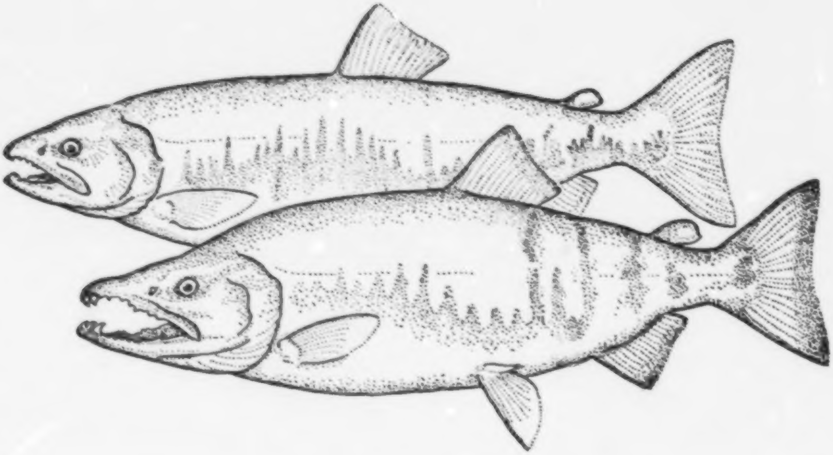
Salmo gorbuscha — Walbaum 1792: 69 (type locality Kamchatka, USSR)
Salmo Scouleri (Richardson) — Richardson 1836: 158
Oncorhynchus Scouleri — Suckley 1862b: 313
Oncorhynchus gorbuscha — Jordan and Gilbert 1883a: 305
Oncorhynchus gorbuscha (Walbaum) — Jordan and Evermann 1896–1900: 478

Etymology *Oncorhynchus* — hooked snout; *gorbuscha* — Russian name for this fish in Alaska.

Common names Pink salmon, pink, humpback salmon, humpback. French common name: *saumon rose*.

CHUM SALMON

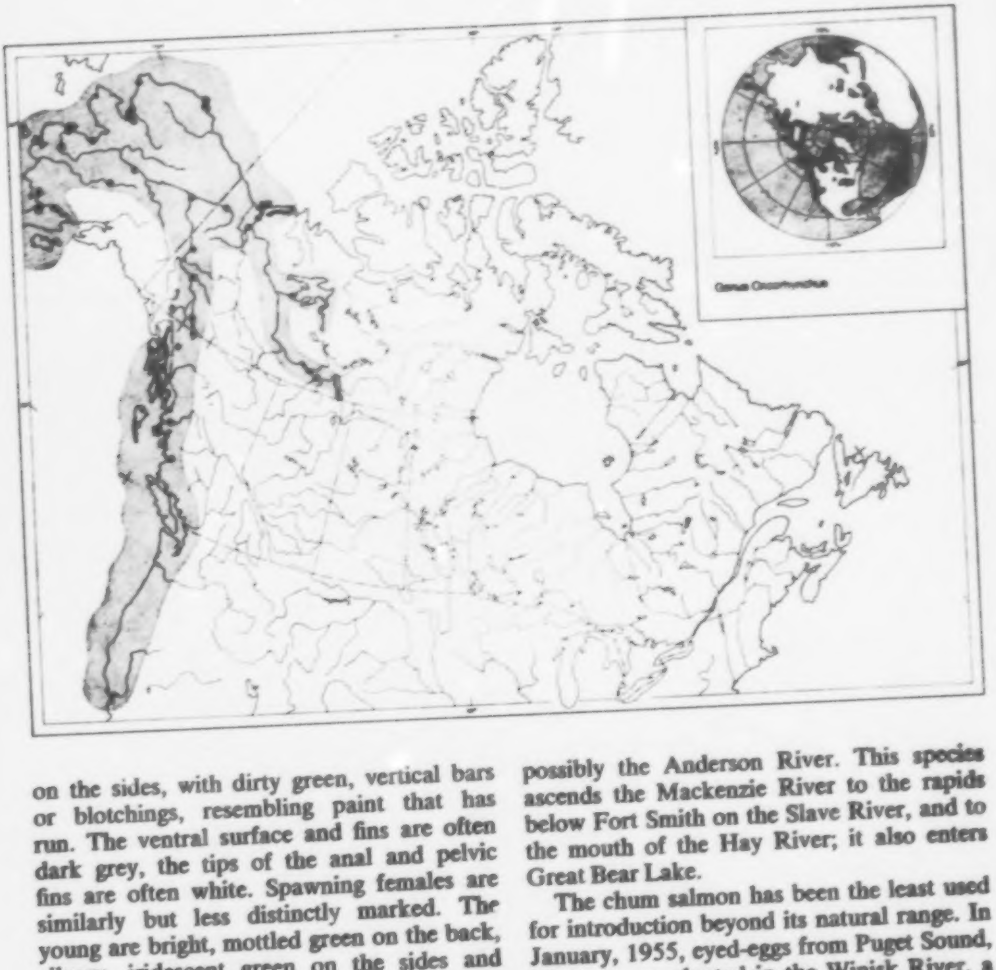
Oncorhynchus keta (Walbaum)



Description Body fusiform, streamlined, laterally compressed, usually about 25 inches (635 mm) in length and 10 pounds in weight as mature adults; body depth somewhat greater than other species, greater in breeding males. Head approximately 22% of total length (much longer in breeding males), conical; eye not large, apparent position variable with sex and condition; snout normally moderate and bluntly pointed but greatly extended, compressed and turned down at tip in breeding males; mouth terminal, normally very little oblique but greatly deformed, unable to close, lower jaw enlarged and turned up at tip in breeding males; premaxillaries not protractile; maxillary extends beyond eye; teeth well developed, sharp, on jaws, head and shaft of vomer, palatines and tongue, no teeth on basibranchials. Gill rakers smooth, short, stout, widely spaced, 11–17 on lower limb, 5–9 on upper limb. Branchiostegal rays 12–16. Fins: large, fleshy dorsal adipose present; dorsal 1, near centre of body, soft rayed, neither high nor long, edge square to slightly emarginate, usually 10–14 principal rays; caudal rather broad, shallowly forked, tips pointed; anal with long base, not high, edge square, 13–17 principal rays; pelvics abdominal, not long, axillary process obvious, fin rounded, 10 or 11 rays; pectorals low, moderately long, tip a rounded point, 14–16 rays. Scales small, cycloid, deeply embedded in spawning individuals; lateral line complete, almost straight, 124–153 lateral line scales. Pyloric caeca 140–249. Vertebrae 59–71.

No nuptial tubercles but breeding males with more compressed body and head, prolonged, hooked snout; gaping mouth; large, bared teeth (hence alternate common name dog salmon); slight hump before dorsal fin, embedded scales, and a distinct colour change; females change less.

Colour Larger individuals in the sea are steel-blue on back and upper sides, the sides are silver and the ventral surface silvery to white, no distinct black spots on back, sides, or fins but upper sides and back may be finely speckled with black. There are tinges of black on the tips of the caudal, anal, and pectoral fins of males. Spawning males are dark olive to almost black above, grey-red



on the sides, with dirty green, vertical bars or blotchings, resembling paint that has run. The ventral surface and fins are often dark grey, the tips of the anal and pelvic fins are often white. Spawning females are similarly but less distinctly marked. The young are bright, mottled green on the back, silvery, iridescent green on the sides and ventral surface, the sides are marked by 6–14 narrow, short parr marks, most of which do not cross the lateral line, or cross it very little, space between adjacent parr marks wider than a parr mark. The fins are white.

Distribution As marine adults this species is found in the Pacific and Arctic oceans, the Sea of Japan, Okhotsk and Bering seas from the Sacramento River in California to Pusan, Korea. In the Arctic Ocean, it extends west to the Lena River, and east at least to the Peel and Mackenzie rivers and possibly the Anderson River. This species ascends the Mackenzie River to the rapids below Fort Smith on the Slave River, and to the mouth of the Hay River; it also enters Great Bear Lake.

The chum salmon has been the least used for introduction beyond its natural range. In January, 1955, eyed-eggs from Puget Sound, Wash., were planted in the Winisk River, a river tributary to Hudson Bay. In June, 1955, fingerlings (eggs presumably from same source), hatched and reared at a Thunder Bay hatchery, were liberated in the Attawapiskat River, which flows into James Bay. This attempt to establish chum salmon in the Ontario section of Hudson and James bays failed.

Biology Various details were derived from a number of published studies and from a summary by Neave (1966). The time that mature fish migrate to the spawning rivers differs with location. In northern British Columbia they arrive on the spawning grounds as early as July. In the south they begin to arrive at the mouth of some streams in September, and arrival on the spawning grounds varies from September to early January. There are distinct autumn and summer runs. In general, they are looked upon as the latest salmon to arrive on the spawning grounds in British Columbia.

Chum salmon arrive at the mouths in an advanced state of sexual development, frequently spawn in tidal areas, show less ability than other species to surmount obstacles, and rarely penetrate rivers more than 100 miles. They do, however, move farther up in such rivers as the Babine, Yukon, Kuskokwim, and Mackenzie. In the Yukon, the main run ascends over 1200 miles, arriving on the spawning grounds above Dawson in late September. However, others spawn in July not far from the mouth. As a result of this wide spread of time and area there is no known correlation between water temperature and spawning.

The males are aggressive on the spawning grounds. The female prepares the redd by facing upstream, lying on one side and vigorously lashing the tail up and down to displace sand and silt. The average size of redds in Washington was 2.7 square yards (2.26 m²), consisting of an elongate trough up to 16 inches (406 mm) deep with a downstream ridge of gravel. However, spawning takes place over substrates ranging from medium gravel to bedrock strewn with boulders. In the latter case, eggs are released and simply fall into the crevices. A single female is often attended by more than one male, and may build and spawn in more than one nest. A single male may spawn with more than one female. The male and female settle in the nest, their mouths gape, and eggs and milt are released during rapid vibration of the two fish. After the eggs are laid the female partly fills the nest by digging again at the upstream end. Egg number per female is variable with size, area, and year, and may reach 4000 but usually varies from 2400 to 3100. The eggs are large, usually 5.1–5.9 mm in diameter in the ovary, but said to be 6–7 mm in diameter (McPhail and Lindsey 1970) or 8.0–9.5 mm when fertilized (Mahon and Hoar 1956). Eggs are demersal and orange in colour. Details of embryonic development were given by Disler (1953), and by Mahon and Hoar (1956). The female guards the nest as long as she is able but the adults die in a few days without returning to the sea. Chum salmon may be in an advanced stage of sexual maturity when they reach fresh water, spawn almost immediately and total adult life in fresh water may not exceed one week. Some Russian workers suggest the female stays over the nest for 2–10 days protecting it from other females.

Depending on water temperature, hatching occurs from late December to late February. The newly hatched alevins, about 20.5 mm long when hatched, remain in the gravel until conditions for seaward migration develop. During the waiting period they live on the yolk. In late April or early May when they are about 1.3 inches (33.2 mm) long, they struggle up through the gravel, and leave the nest. Sparrow (1968) gave range of fry length in fresh water in various British Columbia localities from March to June as 1.2–2.6 inches (32–67 mm), and weight as 0.3–2.5 grams. Where the spawning grounds are close to the sea, the fry move down the first night after emergence, often covering the distance in one night. Where the migration is longer they hide in the gravel during the day and move by night. In certain long migrations or cases of high water, they travel by day as well and form schools earlier than other stocks. Very often chum and pink salmon fry migrate together from nearby spawning grounds. In some areas they spend several weeks in fresh water. At times the fry school before they reach the sea but they always form schools in estuarial water. They can be as large as 2.7 inches (70 mm) at this time. They often remain near shore for several months before they disperse into the sea and are usually gone from the shore by late July or early August. Individuals, 4.7–9.8 inches (120–250 mm) in length, have been taken in the Strait of Georgia and Dixon Entrance as late as early September and, rarely, to November.

The following table shows age-length relation for chum salmon from several localities.

		Age			
	FL	2+	3+	4+	5+
Fraser R., B.C. (Chatwin 1953)	*inches*	–	26.8	28.8	32.5
	mm	–	681	732	826
Johnstone Strait, B.C. (Chatwin 1953)	*inches*	–	25.5	28.5	31.1
	mm	–	648	724	790
Yukon R., Alaska (Gilbert 1922)	*inches*	23.5	25.5	27.4	–
	mm	597	648	696	–
	Wt(*lb*)	6.1	7.5	9.6	–

Most chum salmon in British Columbia mature in their third or fourth year of life. However, Pritchard (1943) reported that ages 2–7 were present in the commercial catches but that 2-year-olds were rare and the 7-year determinations required confirmation. Fish in their fifth year occur regularly but form only a very small part of the returning stock in many streams. At Hooknose Creek, King Island, fish of ages 3, 4, and 5 represented the following percentages of the total number returning: 19.7, 71.8, and 8.5; whereas at Nile Creek, Vancouver Island, they represented 24, 76, and 0. Third and fourth year fish usually constitute 90–99% of the upwardbound run, but one or the other year may predominate in different years or in different streams. Average age seems to increase with distance from the mainland and toward the north. Details of age determination by scales for this species were given by LaLanne and Safsten (1969). Chum salmon are considered to exhibit a strong tendency to home to the natal stream but the degree to which they wander is not well known. A tagged adult was captured, 6 months later, 3000 miles from the site of tagging. There are so-called summer and fall runs in different places.

The average individual returning to spawn in British Columbia 1952–1960, weighed 11.0–12.8 pounds, but weights to 45 pounds are known. Males grow faster and larger than females. Specimens captured in Great Slave Lake were 23.6–24.6 inches (600–625 mm) in length, and one was so emaciated it was only 15 mm thick. Others taken near Aklavik in 1937 and 1938 were as large as 27½ inches (698 mm) and as heavy as 8½ pounds. Chum salmon in the fishery infrequently run as large as 36 inches (915 mm) but the average length is 25 inches (635 mm). When the adults appear at the river mouths secondary sexual characteristics have begun to develop.

The spawning territory varies considerably but is rarely far upstream except in Alaska and the Arctic, and adults rarely attempt to negotiate barriers of any consequence. This species utilizes almost all the suitable rivers along the Pacific coasts (880 streams in British Columbia) and there is not the concentration in a smaller number of streams evident in the case of the pink salmon. The upper lethal temperature has been experimentally determined as 74.8° F (23.8° C). Greatest preference was for temperatures between 53.6° and 57.2° F (12°–14° C) and temperatures above 59° F (15° C) were generally avoided (Brett 1952).

The fry spend so little time in fresh water it was long assumed there was little or no feeding there. Sparrow (1968) contrasted this with several Russian records of feeding, and reported extensive feeding in the Cowichan River. A variety of insects, mature and immature, were included, as well as copepods and nematodes. Chironomid larvae predominated. Growth of these fry was accelerated over that in other areas where no food was taken.

In the early stages of marine life, food varies with season and area, includes a wide variety of organisms such as diatoms, chaetognaths, ostracods, cirripeds, mysids, cumaceans, isopods, amphipods, decapods, dipterous insects, and fish larvae. Copepods, tunicates, and euphausiids dominate the diet of the young and of the older fish at sea. Other items eaten at sea are fishes, copepods, pteropods, and squid. Adults in fresh water do not take food.

Young chum salmon on the spawning grounds and during downstream migration are preyed on by cutthroat and rainbow trout, Dolly Varden, coho salmon smolts, squawfish, and sculpins. Hunter (1959) estimated that in a single stream coho smolts, prickly sculpin, and coastrange sculpin consumed approximately 500,000 pink and chum fry per year. Kingfisher, merganser, other predaceous birds, and mammals are also responsible for a small loss. Even stonefly larvae and possibly other predaceous insects may prey on eggs and alevins. Water temperature, floods, droughts, other fluctuations in water level, spawning competition, and poor returns of adults, control number of young to a far greater extent. For details of factors controlling populations *see* Wickett (1958). Where adults migrate long distances from the sea, bears, some other mammals, and birds such as osprey and eagles, prey on them or remove the dead and dying spent spawners. Adults at sea are preyed on by man, marine mammals, lampreys, and, in the early sea life, possibly by large fishes.

Hoffman (1967) listed the following parasites of this species in North American fresh waters: the protozoan *Myxosoma squamalis*; the trematode *Nanophyetus salmincola*; cestodes *Pelichnibothrium speciosum*, *Phyllobothrium ketae*, *Proteocephalus exiguus*, and *Triaenophorus crassus*.

United States and Japanese scientists found that chum salmon at sea are parasitized by more than 30 species of protozoan and metazoan parasites. The frequency and intensity of infection by the larval nematode *Anisakis* sp. and by the acanthocephalans *Echinorhynchus gadi* and *Bolbosoma* sp. was greater off Asian than North American coasts.

The chum salmon is known to hybridize in nature with the pink salmon if not with others. Simon and Noble (1968) described the artificial cross of these two species and mentioned a report of a cross between the chum salmon and the Pacific cod. Foerster (1935) dealt with various artificial salmon hybrids.

Relation to man The chum salmon has always been of importance to native people, particularly in the north, as food for themselves and their dogs. They still capture large quantities, in nets and fishwheels, which they smoke and dry. Hoar (1951) summarized the Canadian commercial fishery from 1917 to 1947. The chum and pink salmons referred to as "autumn salmon" were long considered less desirable, cheaper species and were of a lesser concern to the fishery. The contribution of chum salmon to the catch has steadily increased. Between 1951 and 1963 it was the fourth most abundant in British Columbia with an average yearly Canadian catch of 2.8 million fish weighing 32.82 million pounds. There were also drastic declines over that period and the average catch between 1955 and 1963 was 2.01 million fish. The catch in 1968 was approximately 36.5 million pounds with a landed value of 1.6 million dollars.

They are taken mainly by purse seines and gillnets, in inside passages and inlets, from mid-June to the end of November, with largest catches from August to October. Some chums are taken by troll fishermen. Large quantities are sold fresh, some are frozen or dry salted, or smoked, but the bulk of the catch is canned. The flesh is white with a creamy tinge and is the lowest of all the salmons in fat content.

Chum salmon are not considered a sport fish and are not regularly sought after by anglers.

Nomenclature

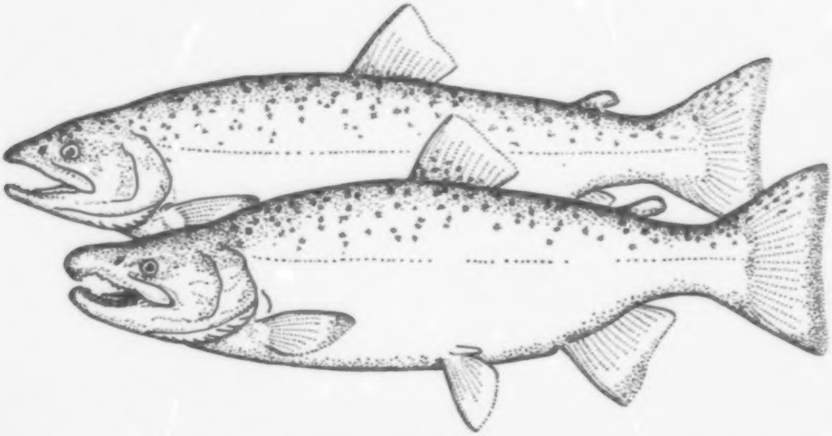
Salmo keta vel kayko — Walbaum 1792: 72 (type locality rivers of Kamchatka, USSR)
Salmo dermatinus — Richardson 1854: 167
Salmo consuetus — Richardson 1854: 168
Salmo canis — Suckley 1862b: 312
Oncorhynchus canis — Suckley 1862b: 313
Oncorhynchus dermatinus — Suckley 1862b: 313
Oncorhynchus consuetus — Suckley 1862b: 313
Oncorhynchus lagocephalus — Günther 1866: 161
Oncorhynchus keta — Jordan and Gilbert 1883a: 305

Etymology *Oncorhynchus* — hooked snout; *keta* — Russian name for this salmon.

Common names Chum salmon, chum, dog salmon, keta. French common name: *saumon keta.*

COHO SALMON

Oncorhynchus kisutch (Walbaum)



Description Body fusiform, streamlined, laterally compressed, usually 18–24 inches (457–610 mm) in length and 8–12 pounds in weight as marine adults and 10.8–25.8 inches (279–656 mm) fork length in Great Lakes freshwater populations; body depth moderate, greater in breeding males. Head approximately 22% of total length, longer in breeding males, conical; eye not large, position variable with sex and condition; snout normally bluntly pointed but greatly extended, thickened and turned down at tip in breeding males; mouth terminal, slightly oblique, deformed in breeding males with lower jaw enlarged, turned up at tip, mouth unable to close; premaxillaries not protractile; maxillary extending well beyond eye; well-developed, sharp teeth on both jaws, head and shaft of vomer, palatines, and tongue, no teeth on basibranchials (= hyoids). Gill rakers rough, widely spaced, 18–25 with 12–16 on lower limb and 6–9 on upper limb. Branchiostegal rays 11–15. Fins: rather long, thin dorsal adipose present, dorsal 1, at centre of body, soft rayed, neither high nor long, edge square to slightly emarginate (often rounded in young), usually 9–12 principal rays; caudal broad, usually only emarginate, tips pointed; anal not particularly high, edge square or with a small rounded lobe anteriorly (large and with protracted first rays in young), usually 12–17 principal rays; pelvics abdominal, not long, axillary process obvious, fin rounded, tip somewhat pointed, 9–11 rays; pectorals low, rather long, somewhat pointed, 13–16 rays. Scales small, cycloid; lateral line complete, almost straight, 121–148 lateral line scales. Pyloric caeca 45–114. Vertebrae 61–69. *See* section entitled *Systematic notes* for meristics of Great Lakes populations.

No nuptial tubercles, but breeding males with more compressed head and body, snout thick and hooked but less deformed than in other species, teeth enlarged, more exposed, hump little or not developed, scales embedded, some colour change; females change little and changes in males of permanent freshwater populations less spectacular.

Colour Adults in ocean or Great Lakes are steel-blue to slightly green on dorsal surface, sides brilliant silver, ventral surface white, small black spots on back, sides above lateral line, base of dorsal fin, and upper lobe of caudal fin. In breeding males the back and head are darker, dirty blue-green, the sides are dull with a brilliant red stripe, ventral surface grey to black. The lower gums are usually pale not black in marine populations. In the Great Lakes most do have grey to black gums. Colour is less spectacular in Great Lakes males and change much less pronounced in females generally.

The young are blue-green on the back, with silvery sides and 8–12 narrow parr marks. The lateral line runs through the centre of most of them, and the pale area between parr marks is greater than the width of a parr mark. The adipose fin is uniform, dusky; the caudal fin and most of the anal fin red-orange. The anal fin is large, the first rays elongate and white with black behind. However colour varies greatly from river to river.

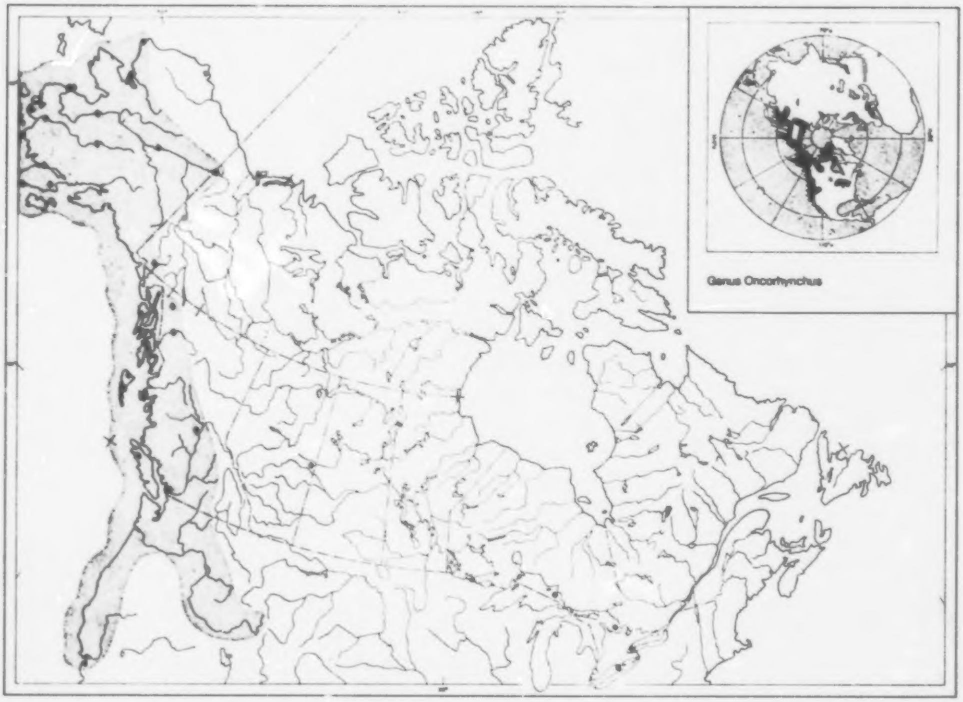
Systematic notes The range of values for various meristic characters is broad but fairly uniform over the distribution in the Pacific. It is interesting to note effect on meristics of moving a species with rather plastic characters, from different areas of its natural range, subjecting them to different embryonic development in different eastern hatcheries and liberating them into the same exotic habitat, as well as into the wide range of conditions from Lake Superior to Lake Ontario. The following table (W. J. Christie and ROM records) compares meristics of coho salmon planted in Lake Ontario by New York State (origin Washington via Michigan?) in 1968 and in 1969, and by Ontario in 1969 (origin Michigan) with the general figures given in the description.

	Ontario	New York	New York	
Character	1969	1968	1969	Pacific
Gill rakers	21–23	–	–	18–25
Dorsal rays	10–12	10–12	10–11	9–12
Anal rays	12–14	13–15	13–14	12–17
Pelvic rays	9–10	9–11	10	9–11
Pectoral rays	12–15	13–15	14	13–16
Lateral line scales	112–133	127–139	114–124	121–148
Pyloric caeca	76	68–79	–	45–114

The Lake Ontario sample is small and values may eventually spread to fill the range of anadromous populations. Presently, however, number of anal rays, lateral line scales, and pyloric caeca tend to be lower in Lake Ontario. Early attempts to identify salmon from the Great Lakes and to provide characters to separate exotic salmon from rainbow trout, led to confusion as a result of depending, for the salmon, on published figures of meristics of Pacific populations. It would be useful to expand this comparison now that coho salmon are available in all the Great Lakes, from at least three liberations (Michigan, New York, Ontario) and possibly from several different original sources.

Distribution This species occurs naturally only in the Pacific Ocean and its tributary drainage. It is known in fresh water in North America from Monterey Bay, Calif., (in the sea infrequently to Baja California) to Point Hope, Alaska. In Asia, it occurs from the Anadyr River, USSR, south to Hokkaido, Japan.

The states of Alaska, Washington, Oregon, and California have long maintained, by fish culture, stocks in freshwater lakes for angling. Montana had limited success with a 1948 introduction. In the early 1900's attempts were made to introduce the coho



into the Atlantic from Maine to Maryland, and in Argentina and Chile. Chile was the only country reporting at least early success. Coho are apparently present in New Hampshire fresh waters.

The history of the attempts to establish this species in the Great Lakes goes back to 1873. Between 1873 and 1878 thousands of fry were liberated in Lake Erie and its tributary rivers by Ontario, Ohio, and Michigan. There was no success. In 1933, Ohio again attempted to establish them in Lake Erie. From 1933 to 1935, cohos of 3–5 pounds were taken, but the stocks did not succeed. The greatest excitement generated by liberations were those commenced in the Great Lakes in 1966 by Michigan and followed later by Ohio, New York (1968), and Ontario (1969). These stocks are presently being maintained by fish culture rather than by dependence on doubtful natural reproduction, but there have been indications of natural reproduction in Michigan.

Alberta planted coho salmon in Cold Lake in May 1971, and there have been reports of fish from this source captured downstream in Pierce Lake, Sask. They now occur in Canada in all the Great Lakes, and in Alberta, as well as in their native range.

Biology Details derived mainly from Shapovalov and Taft (1954), Godfrey (1965), and Tody and Tanner (1966). The adults migrate from the sea or lake late in the season (later than sockeye and pink salmon) and over a prolonged period. They school at the mouths of rivers and often move in when fall rains increase river flow. The spawning run in the Great Lakes is from early September to early October. Adults move upstream during the day. They sometimes utilize the whole length of smaller rivers, penetrating beyond sockeye, pink, and chum salmon, but more often do not travel more than 150 miles from the sea in large rivers. Segregation into summer and autumn, or autumn and winter runs is more apparent in Asia than in North America. Spawning takes place in swifter water of shallow, gravelly areas of river tributaries, from October to March, but usually October to November, or November to January in North America. On the spawning grounds males and females are aggressive. The nest is built by the female, which, by lying on her side and beating the tail vigorously up and down, excavates a long oval to round trough in medium to small gravel. Several males may be in attendance but one (larger) is dominant. The dominant male swims into the nest with the female, their mouths gape, the two vibrate, and eggs and sperm are released. The other attendant males (smaller jacks or grilse?) may dart in at this time and release sperm. The female may spawn in as many as four different nests, probably with different males. After the eggs are laid they are covered by digging and displacing gravel from the upstream edge of the nest. Egg number is variable with size of female, area, and year, and has been reported in Washington to be 1440–5700 for females 17.3–28.3 inches (440–720 mm) in length. Average number in British Columbia ranges from 2100 to 2789. The eggs are large, those of west coast populations usually have a diameter of 4.5–6.0 mm, but are smaller than in some other salmon. Eggs taken from females from Lake Ontario were 6.6–7.1 mm in diameter after preservation, outside the range given for the western anadromous populations. They are orange-red in colour and demersal. After covering the nest the female guards it as long as she is able. Soon after spawning is completed the adults die. Details on early development were given by Ievleva (1951). Hatching usually takes place in early spring, in 35–50 days, 38 days at 51.3° F (10.7° C) to 48 days at 48° F (8.9° C) in California, possibly 42–56 days farther north and as much as 115 days in Asia. The alevins remain 2–3 weeks in the gravel, at least until the yolk is absorbed, and then emerge as free-swimming, actively feeding fry. Because of the spread in spawning time, fry emergence occurs from early March to late July.

Apparently some fry migrate almost immediately to the sea or lake but most remain at least 1 year in freshwater or lake tributaries (1 year in British Columbia and 2 years in the Yukon River). Those remaining in the spawning stream take up residence in nearby shallow, gravel areas near the stream bank, feed voraciously, and grow quickly. They congregate in schools at first but later disperse and become aggressive and territorial. In the late summer to fall they move into deeper pools. Usually in late March or April (February to June) of the year (or second year) following their emergence, most of the fish begin to migrate to the ocean or lake. At this time the one-year-olds are about 4 inches (100 mm) long, are referred to as smolts, turn silvery, and, on the Pacific coast, go through physiological changes in preparation for life in salt water. They usually migrate in small schools, mainly at night, and generally arrive at the river mouth in late May (April to August). Not all progeny of anadromous coho migrate, and in various lakes and streams there are cohos older than 2 years (residuals) which never migrate to sea. They do mature but never spawn and consequently all residuals are the progeny of successive runs of anadromous parents. In Cultus Lake, B.C., these residuals grow to 18.3–23.4 inches (465–594 mm) (Foerster and Ricker 1953). Cohos that migrate to the sea (and probably in Great Lakes also) remain close to shore for the first few months and then move to the open ocean (or lake). They do not usually migrate far, but tagged individuals have been caught up to 1200 miles from the tagging site. Most coho spend about 18 months (two summer seasons) in the sea or lake and return to spawn in the fall, usually at age 3 or age 4. The number of 4- and 5-year-old fish in the run of anadromous coho increases northward. In some southern areas of British Columbia the spawning run can consist of 2-year-old precocious males (jacks) and, rarely, females (= first fall following downstream migration), and the more usual 3-year-old fish. In Cultus Lake, B.C., the older fish are usually 21–30 inches (533–762 mm) in length and the jacks are 10.5–13.5 inches (267–343 mm). About 85% of the spawners home to their natal stream. Straying or wandering of adults is apparently greater in the Great Lakes than in the marine populations (*see* the history of the Great Lakes introductions in section called *Relation to man*).

The only freshwater habitat of the marine adults is the spawning stream which is usually a small, coastal, gravelly stream, or a similar tributary of a larger river. The young that remain in spawning streams have, at first, a habitat near shore in gravelly shallows; later they move into deeper pools below riffles, often around large boulders or log jams. They are active in summer and feed voraciously. Activity and feeding decreases considerably in winter. Coho residuals utilize the shallow waters of the whole of smaller lakes or are residents of larger streams. Great detail on the life of young coho in fresh water and their interaction with trout was given by Hartman (1965). Upper lethal temperature for coho fry was determined experimentally (Brett 1952) to be 77.2° F (25.1° C), and preferred temperature 53.6°–57.2° F (12°–14° C).

Young coho in fresh water in Alaska feed mainly on insects including dipterous larvae, Trichoptera, Plecoptera, and Coleoptera. Small quantities of oligochaetes and spiders are also eaten. Sockeye salmon fry are often next to dipterans in importance (Roos 1960). Large numbers of chum and pink salmon are consumed by young coho. When they enter the sea, the smolts (over 100 mm in length) are predaceous and feed on pink and chum fry, herring, sand lance, other fishes, squid, and Crustacea. Probably larger young in the Great Lakes prey on young fishes. The food of the marine adults is more pelagic and more varied than that of many Pacific salmon. It consists of fish (80%), invertebrates (20%), and includes the following: pilchard, herring, anchovy, coho salmon, capelin, lanternfish, Pacific saury, hake, whiting, rockfishes, black cod, sculpins, sand lance, squid, barnacles, isopods, amphipods, euphausiids, crab larvae, and jellyfish. Herring and sand lance make up 75% of the volume (Pritchard and Tester 1944). Food varies from place to place and with time, and a detailed analysis of food of ocean dwelling coho was given by Prakash (1962). It is obvious from this list why it was hoped coho in the Great Lakes would utilize the very abundant rainbow smelt and alewife. This they have done as these two species make up the bulk of the food of larger cohos taken.

Coho salmon have been attacked by river lamprey in the Skeena River, B.C. Coho fry (and smolts), especially when aggregated and abundant, are preyed on by a variety of fishes. In the west these include coho smolts, cutthroat and rainbow trout, Dolly Varden, squawfish, and sculpins. Mergansers, loons, kingfishers, other birds, and some small mammals, may also take numbers of young. All these predators sometimes gorge themselves on young migrating salmon. In the Great Lakes some warmwater predators will probably be added to this list. The adults in the west are taken during their spawning run by bears, other mammals, and large birds. In the ocean, man, lampreys, and aquatic mammals such as seals and killer whales are the chief predators. Individuals in recent spawning runs to tributary rivers of Lake Ontario have shown multiple scars of the sea lamprey.

As young, the fry and smolts will compete with all other bottom feeders. As adults in the ocean or Great Lakes, the adults will be competitors of other predaceous fishes such as the rainbow and lake trouts. However, coho probably feed at depths much shallower than those used by lake trout and are dominated in a competitive situation by rainbow trout; thus they may not adversely affect either of those species, or other highly valued predatory species in the Great Lakes.

Bangham and Adams (1954) examined 132 specimens from seven freshwater locations in British Columbia, and found 88 infected. Parasites identified were trematodes *Crepidostomum farionis*, *Diplostomulum* sp., Gyrodactyloidea; nematodes *Hepaticola bakeri*, *Metabronema salvelini*, *Philonema oncorhynchi*, *Rhabdochona cascadilla*; cestodes *Diphyllobothrium* sp., *Proteocephalus* sp., and acanthocephalans *Neoechinorhynchus rutili* and *Pomphorhynchus bulbocolli*.

Boyd and Tomlinson (1965) reported on the presence of spores of the myxosporidian parasite *Henneguya salminicola* in the body musculature of cohos. This parasite causes a "milky" condition in the flesh of the fish it infests.

Hoffman (1967) listed fungi (1), protozoans (10), trematodes (8), cestodes (8), nematodes (7), acanthocephalans (3), and crustaceans (1), from this species in the fresh waters of North America and Russia.

Natural hybrids of this species and the chinook salmon are known. Anglers in Ontario turned in a specimen which was tentatively identified by the Ontario Department of Lands and Forests (now Ministry of Natural Resources) as a coho × rainbow trout hybrid. *See* Foerster (1935) for results of artificial hybridization of salmons.

Relation to man The coho has long been of considerable importance as a commercial fish and as a sport fish in British Columbia. From 1951 to 1963 the annual commercial catch there was 3.04 million fish weighing 21.54 million pounds. The catch of 29.99 million pounds in 1968 had a landed value of 10.45 million dollars. The usual size of fish in the catch is 8 pounds, ranging from 5 to 12, with 20 pound fish not uncommon. Some immature fish or grilse (up to 3 pounds) are taken by the commercial fishermen in the Strait of Georgia. The best catches are made from July to September, with a peak in August.

Cohos are taken by gillnets and purse seines from the inlets in August, but the most important catches are those of the trollers which begin in June but are most successful from mid-July to mid-August. They troll large plugs, spoons or feathered jigs. The coho is canned, mild cured, smoked, or, if troll-caught, sold fresh, or fresh frozen, as choice and fancy quality. The wholesale price in November 1970 in the east was $1.15/pound for fresh-frozen coho. The fishery was summarized by Milne (1964).

Cohos are taken by marine anglers from July to October and the larger fish taken are those in their last year of sea life. The presently listed angler record is a coho weighing 31 pounds that was caught in Cowichan Bay, B.C., in 1947. However, a coho taken recently in the Manistee River, Mich., weighed 33 pounds. They are also caught late in their first ocean year and called grilse or blueback (silvers in the United States, as blueback is used for smaller sockeye). At this time they are 4–8 pounds. Plugs, spoons, and jigs, like those used by the commercial trollers but smaller, are the standard tackle for coho salmon. Fly fishermen using large bucktail flies take coho when they are concentrated at stream mouths, and they are pursued by anglers as far upstream as they remain silvery and take food. Frozen or pickled herring are also used, and a small industry developed to prepare this bait. British Columbia anglers catch, on the average, 85,000 older and 110,000 grilse per year.

The dramatic results of the introduction of coho into the Great Lakes has resulted in a phenomenal explosion of interest in this species. The introduction, first by the State of Michigan in lakes Michigan, Huron, and Superior, began in May 1966, with 4–6 inch (102–152 mm) smolts. In September 1966, Michigan commercial fishermen took many 17-inch (432-mm) jack coho up to 2½ pounds weight, and an angler caught one 23½ inches (597 mm) long, weighing 7 pounds. This set off a wild fishing fever, and a near catastrophe, in which thousands of anglers, in boats as small as canoes, were up to 2 miles offshore on these large lakes during the stormy time of year. Michigan anglers caught about 2000 coho averaging 2 pounds weight. In the spring and summer of 1967 the stock spread widely and Canadian anglers started catching coho in Georgian Bay and Lake Erie. In September 1967 large runs of mature 4-year-old fish returned to the Michigan streams. About 31,000 were taken with an average weight of 11½ pounds and some as heavy as 20 pounds. In the first 9 months of 1970 United States anglers took 700,000 pounds of coho from the Great Lakes.

New York introduced coho in Lake Ontario, starting in 1968. Most of the early recoveries were made in Ontario and were fish as large as 24.2 inches (615 mm) in length and up to 8 pounds in weight. In the spring of 1969, Ontario introduced coho into rivers flowing into western Lake Ontario, and Nipigon Bay, Lake Superior.

Eggs from Michigan, reared in Ontario, were the source of the smolts used. In April 1969, Ontario anglers were still catching strays of the Michigan stock and Ontario commercial fishermen were catching and marketing up to 9000 pounds of fish of Michigan origin, which Michigan commercial fishermen were prohibited from catching. Some of these fish taken by anglers in October–November 1969, in Georgian Bay were up to 27 inches (686 mm) long and 17½ pounds weight. A 32-inch (814-mm) fish of 11.1 pounds was caught at Port Bruce in Lake Erie. Since that time, some of the smolts introduced into the Ontario side of Lake Ontario returned in 1970 to spawn, as 3-year-olds, with a mean length of 25 inches (635 mm) and weight of 5 pounds. The cohos are definitely utilizing the alewife and smelts, and, more rarely, even lampreys, to achieve this extremely fast growth.

Several factors are involved in the future success of this most recent attempt to establish Pacific salmon in the Great Lakes, and in the possibility that this introduction will have longer-lasting results than did the former ones. These are: the ability of the coho to reproduce naturally or the decision that the stock is economically worthy of maintenance by means of constant fish-cultural activity; maintenance of habitat conditions which will ensure survival of the coho stocks and stocks of food fishes; and the ability of these exotic fishes to live through what appears to be a high rate, at least in Lake Ontario, of sea lamprey attack.

Nomenclature

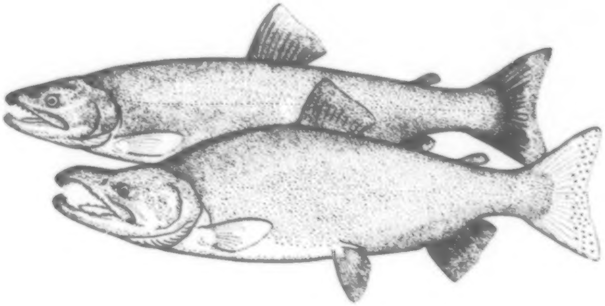
Salmo kisutch — Walbaum 1792: 70 (type locality rivers and lakes of Kamchatka, USSR)
Salmo tsuppitch — Richardson 1836: 224
Oncorhynchus kisutch (Walbaum) — Jordan and Evermann 1896–1900: 480

Etymology *Oncorhynchus* — hooked snout; *kisutch* — vernacular name for this species in Kamchatka.

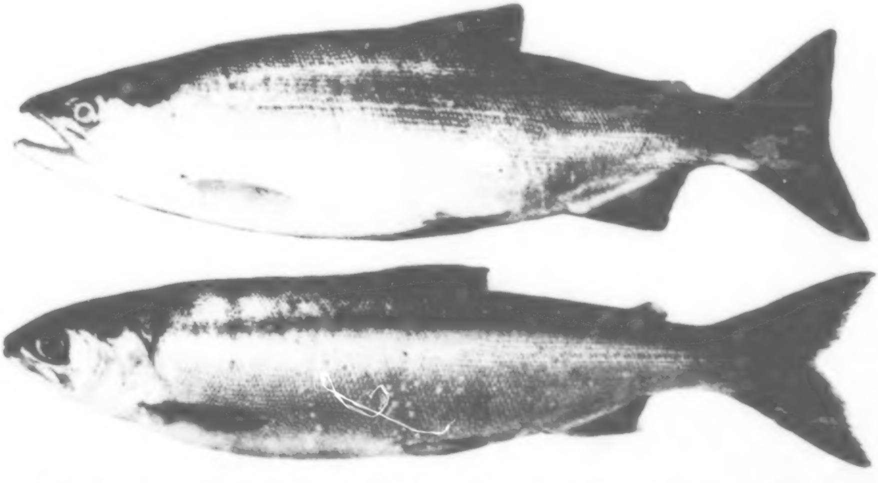
Common names Coho salmon, coho, silver salmon, sea trout, blueback. French common name: *saumon coho.*

KOKANEE AND SOCKEYE SALMON

Oncorhynchus nerka (Walbaum)



Since there are well-known populations of a truly freshwater form of this species, and since there is great interest in its introduction in North America distant from its natural habitat, the kokanee will be emphasized here. Information is provided on the anadromous sockeye salmon in fresh water but anyone interested in that form should see Foerster's (1968) masterful compilation and analysis of available information.



Upper photo, *kokanee from Kootenay Lake, B.C.*; lower photo, *introduced kokanee from Boulter Lake, Ont. (Kootenay Lake stock)*.

Description Body fusiform, streamlined, laterally compressed, usually 8–9 inches (203–229 mm) when mature (sockeye usually 24 inches or 610 mm when returning to fresh water), body depth only moderate, little more in breeding males. Head bluntly pointed, conical, eye rather small, position variable with sex and condition; snout rather pointed; mouth terminal, slightly oblique; premaxillaries not protractile; maxillary extends at least to posterior margin of eye and often beyond; well-developed but rather small teeth on jaws, head and shaft of vomer, palatines, and tongue, no teeth on basibranchials. Gill rakers long, slender, serrated, closely spaced, 31–44 in British Columbia (in sockeye usually 29–43 with 19–27 on lower limb and 10–16 on upper limb). Branchiostegal rays 13 or 14 (11–16 in sockeye). Fins: a rather small dorsal adipose present, dorsal 1, at centre of body, soft rayed, neither high nor long, edge square to slightly emarginate, usually 11–13 principal rays (11–16 in sockeye); caudal broad, moderately forked, tips pointed; anal with long base, low, square, 11–16 (usually 13 or 14) principal rays (13–18 in sockeye); pelvics abdominal, not long, axillary process present, tip of fin a rounded point, 9–11 rays in sockeye; pectorals moderately long, tip a rounded point, 11–21 rays in sockeye. Scales small, cycloid; lateral line complete, straight, 121–140 lateral line scales (120–150 in sockeye). Pyloric caeca 50–87 (45–115 in sockeye). Vertebrae 62–67 (56–67 in sockeye).

No nuptial tubercles but breeding males with more compressed head and body, prolonged, hooked, turned up snout, gaping mouth, very small hump before dorsal fin, embedded scales, and striking colour change. Colour change in females almost equal to males but other changes much less. Spawning sockeye show less deformity of head, snout, mouth, and teeth than do most other Pacific salmons.

Colour Dorsal surface of head and body brilliant steel-blue to green-blue, with no distinct black spots, sides overall bright silver, no markings, ventral surface white to silver, dorsal fin sometimes with a few dark marks, other fins clear to dusky on membranes.

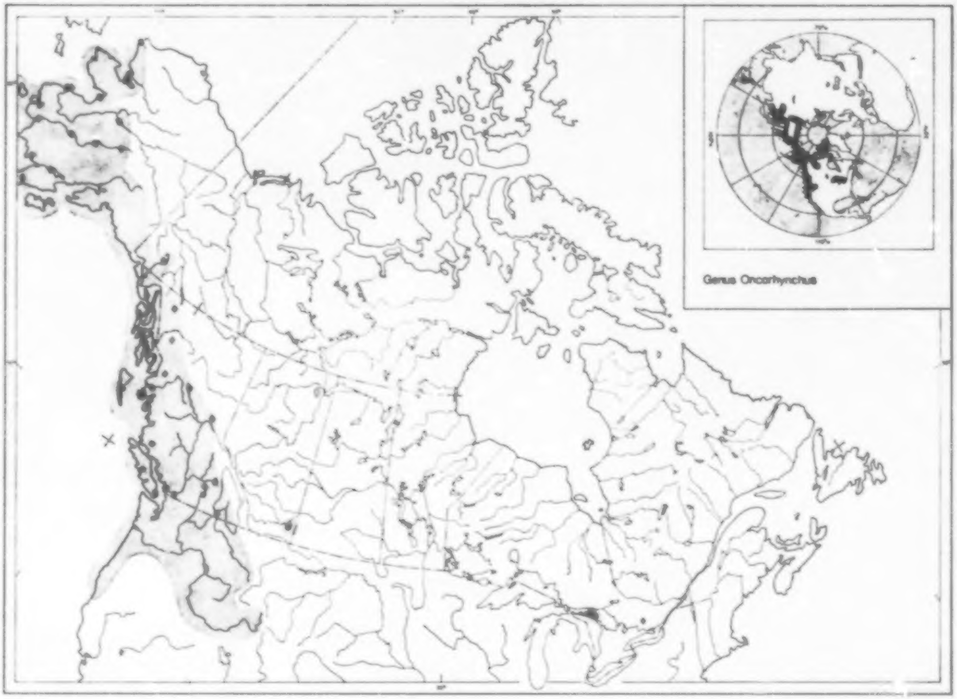
In breeding males back and sides bright red to dirty red-grey, dirty red to grey on ventral surface, head to lower jaw bright green to olive with black on maxillary and snout, lower jaw white to grey; dorsal, adipose and anal fins red, pectoral, pelvic, and caudal fins green to almost black. Female similar but the body is a darker grey-red colour. In some freshwater populations, and in rare anadromous populations, the spawners are dull green to yellow without prominent red colouring. Little difference between kokanee and sockeye salmon.

Systematic notes The permanent freshwater form of this species, the kokanee, was originally described as a separate species, *Salmo kennerlyi* Suckley. Later it was realized that it and the anadromous form were the same species but they were given subspecific status, the sockeye salmon *Oncorhynchus nerka nerka* Walbaum, and the kokanee *O. n. kennerlyi* Suckley. Various studies showing differences in races in the same lake (Vernon 1957), in gill raker count from population to population (Nelson 1968e) and in transplant progeny vs. original stock (McCart and Andersen 1967), the existence in different lakes of so called "residual" sockeye (an intermediate condition), and the fact that kokanee can and will migrate and return with anadromous sockeye under certain circumstances (Foerster 1947), all indicate the futility of separating the two forms.

The kokanee is generally very similar to the anadromous sockeye except in ultimate length and weight, and its meristic characters fall within the range of the sockeye but usually have much smaller extremes.

As mentioned above, there exists, in fresh water, a confusing intermediate form referred to by Ricker (1938b) as "residual sockeye." These sockeye do not migrate, become mature in fresh water at a smaller size, but do not reproduce. They do not occur where there are no anadromous stocks from which they can be derived. *See* Ricker (1940, 1959) for concept of the origin of kokanee. The meristics of Great Lakes populations may deviate from those of the western populations from which they were derived as have the coho salmon in the Great Lakes.

Distribution The kokanee is probably present over most of the range of the sockeye salmon, which extends in North America from the Klamath River, Calif., to Point Hope, Alaska (with stragglers to Bathurst Inlet in the Arctic Ocean), and in Asia from northern Hokkaido, Japan, to the Anadyr



River, USSR. The kokanee occurs naturally in Japan, USSR, Alaska, Yukon Territory (Alsek River), British Columbia, Washington, Idaho, and Oregon (Nelson 1968d). It occurs naturally in many lakes to which anadromous salmon no longer have access, but must have had at one time. The extent of the distribution of true kokanee populations may be clouded by the presence in various freshwater localities of "residual" populations of sockeye that do not reproduce. They occur most widely and abundantly in British Columbia.

Kokanee have been introduced widely in North America including Maine, California, Montana, Colorado, Connecticut, New York, Pennsylvania, Vermont, North Dakota, Nevada, Utah, Wyoming (Buss 1957), farther inland in states where they occur naturally, and in Canada in Alberta, Saskatchewan, Manitoba, and Ontario. They have been introduced into lakes Huron, Michigan, and Superior by Michigan and into lakes Huron (successful) and Ontario (failed) by Ontario.

Biology The biology of the kokanee will be treated here but it will be contrasted with that of the sockeye by providing only brief parallel information on the freshwater life of the anadromous form (mainly from short summaries by Ricker 1966, and Margolis et al. 1966). The most comprehensive summary of the biology of the anadromous form is available in Bulletin 162 of the Fisheries Research Board, entitled *The Sockeye Salmon* (Foerster 1968).

Kokanee spawn in the fall, generally during September and October in Kootenay Lake and elsewhere in British Columbia, and in November and December in Boulter Lake, Ont. Spawning in different areas may be from August to February, over temperatures from 51°–41° F (10.5°—5.0° C) and in 1–30 feet (0.3–9.2 m) of water. Spawning takes place while ice is forming on the lake in Ontario.

The colourful mature adults usually enter inlet streams of the lake in which they are living or they may spawn on gravel beds along its shore. *See* Lorz and Northcote (1965) for details of factors governing spawning run in Nicola Lake, B.C. On the spawning grounds the male (and sometimes the female) is aggressive to other spawning males. The female prepares a nest in streams, in pea-sized gravel, by lying on her side and beating the tail violently up and down. This results in a depression longer than the female and 2–4 inches (51–102 mm) deep, with a rim of gravel at the downstream end. It has been noted that fish spawning in lakes where there is no current, often utilize a vertical, side to side action of the tail characteristic of other lake-spawning fishes. The male and female swim into the nest, their mouths gape, they vibrate, and the eggs and sperm are deposited. The nest is covered by the female, digging at the head end of the nest and displacing gravel into it. The female may dig and spawn in more than one nest, with different males, and a single male may spawn with more than one female. A description of spawning behaviour was given by Schultz and students (1935). Adults of both sexes usually die a few days to several weeks later, but in Ontario some may live most of the winter. Egg number is extremely variable over the range. It varies with size of female, and has been reported to be from 368–1764, with a mean number of approximately 450. Sockeye eggs are 4.5–5.0 mm in diameter and orange-red in colour. Time to 100% hatching, determined experimentally by Fallis (1970), varied from about 140 days at 39.2° F (4° C) to 48 days at 59° F (15° C), and 70–82 days at descending habitat temperatures of 55.4°–41.2° F (13.0°–5.1° C) according to Lindsey (1958). In British Columbia streams with constant winter temperatures just above freezing, spawning is early, hatching occurs in December–January and emergence may not occur until March–May. At that time the young struggle out of the nest and become free-swimming, feeding fry.

Growth is rapid, particularly in the first year. In Boulter Lake, Ont., they achieved a length of 5.5 inches (140 mm) in the first year. It is extremely variable in different habitats. In northern British Columbia they are usually 8–9 inches (203–229 mm) in length at maturity whereas in southern British Columbia they are 12–15 inches (305–381 mm). The following table compares growth from several localities.

Generally, kokanee mature, spawn, and die at 4 years of age, but fish age 2–4 may be in the spawning run and fish as old as 8 years have been seen. Kokanee in British Columbia spawning runs summarized by Nelson (1968b) were as large as 13.4 inches (340 mm) fork length and those in Kootenay Lake, B.C., were 6.3–11.0 inches (160–279 mm) and 295–320 grams in weight. The spawning runs in the Blue Jay and Manitou rivers of Manitoulin Island, Lake Huron, appear to be mostly fish 2 years of age. Kokanee as large as 21 inches (533 mm) in length and weights to 4 pounds are not uncommon. Kokanee as heavy as 8 pounds have been reported.

Kokanee, which in spring and fall may inhabit all depths, usually inhabit the upper middle layers of the open lake during the summer in some areas. They move into deep-

		Age (*years*)			
		1	**2**	**3**	**4**
Moore Creek, Nicola L., B.C. **(Lorz and Northcote 1965)**	**FL** ***inches***	**–**	**6.1–7.3**	**8.0–10.6**	**8.4–10.8**
	mm	**–**	**155–185**	**205–270**	**215–275**
Pend Oreille L., Idaho **(Buss 1957)**	**FL** ***inches***	**2–3**	**7–8**	**8–9**	**10–12**
	mm	**51–76**	**178–203**	**203–229**	**254–305**
Boulter L., Ont. **(Fallis 1970)**	**Avg FL** ***inches***	**–**	**7.5**	**9.4**	**9.8**
	mm	**–**	**190**	**240**	**250**
	Wt (*g*)	**–**	**90**	**160**	**179**

er water with increased summer temperature and in the winter. In summer, they have extensive daily vertical and onshore–offshore movements, possibly associated with temperature and food. Temperature preference is 50°–59° F (10°–15° C). For young sockeye salmon upper lethal temperature is 75.9° F (24.4° C) and preferred temperature is 53.6°–57.2° F (12°–14° C).

The kokanee is mainly a pelagic, plankton feeder but it may derive a significant portion of its food from bottom organisms. Crustacean plankton forms the bulk of the food of adults in summer and autumn in Nicola Lake, B.C., and diaptomids were dominant in the spring. Chironomid pupae were important (up to 70% volume) throughout the summer but larvae contributed in only a minor way and mostly in the daytime. In addition there were miscellaneous zooplankters, terrestrial insects, and water mites (Northcote and Lorz 1966). *Daphnia*, *Cyclops*, *Diaptomus*, *Epischura*, *Chaoborus*, mayflies, and adult dipterans taken at the surface have been mentioned elsewhere as important. Average volume of food in the stomachs appears to be highest in June and October. Volume of food decreases as maturity approaches. The kokanee and young anadromous sockeye salmon eat identical food.

Kokanee, as a result of their plankton diet and open water habitat, may compete little even with other plankton feeding fishes. They are not known to prey on other fishes but small sockeye salmon have been reported eating cottids while the cottids were so small as to be still inhabiting the surface water.

In British Columbia the young are consumed by a wide variety of predaceous fishes including rainbow and cutthroat trout, Dolly Varden, coho salmon, and squawfish. Their role as a food item of predaceous fishes in areas where they have been introduced in the east is presently poorly known. In the Fraser River, they have been found in the stomachs of smallmouth bass and, in the Great Lakes, will no doubt be eaten by larger rainbow trout, lake trout, and coho salmon.

Maturing anadromous sockeye salmon returning to spawn appear in coastal waters from May to October, the time of arrival at river mouth depending on the time of spawning and the length of freshwater migration to the spawning grounds. They usually have a dominant year run and a subdominant year. Elsewhere populations exhibit a striking extreme, 4–5 year, cyclical abundance. They can be at this time 3–8 years of age (usually 4 in southern and 5 in northern parts of the range) and about 24–28 inches (610–711 mm) in length (known to 33 inches or 840 mm) and 5 pounds in weight (known to 15 pounds). Some enter fresh water in May and remain there until fall. The runs to various upriver spawning grounds (= different stocks or races) can be detected at the river mouth by such techniques as scale characteristics (Henry 1961). After reaching a home lake they go to the natal river (usually an inlet) to spawn, but some spend 3–4 months before spawning. Spawning in different areas takes place sometime between July and December, takes place at 37.4°–44.6° F (3°–7° C) and mainly in streams, but in some areas along lake shores.

Egg number and egg size vary with size of female and between stocks. Eggs hatch during the winter or early spring, remain in the gravel until some weeks or months after the yolk is absorbed, and emerge in April to June. Some fry move downstream to the sea shortly after emerging (probably do not survive), most move down (or up) out of the spawning stream to the "nursery" lake and disperse throughout the lake. The fry feed in the open water on plankton crustaceans, chironomid pupae, and at times terrestrial insects. The large number of young resulting from the spawners of a dominant year often deplete the plankton of the nursery lake. In the Fraser River and other southern systems most spend only 1 year in the lake and grow to 2.3–4.1 inches (59–106 mm), but certain stocks spend 2 years and reach 4.0–5.1 inches (101–131 mm) and some, more rarely, spend 3 or 4 years. While in the lakes they are very subject to predation by trouts, Dolly Varden, coho salmon smolts, squawfish, and diving birds. Toward the end of the period of lake residence, characteristic of that stock, the smolts turn silvery and begin physiological changes preparatory to life in the sea.

Seaward migration of smolts occurs in the spring months of their second to fifth year of life. In the ocean sockeye are pelagic, feed on zooplankton, squid, and, infrequently, on small fishes.

After a growth period in the sea of over 1 year (jacks), or more usually 2 or over 3 years, they home to their natal stream to spawn. Some remain in the sea for 4 years. The adults returning to spawn are usually 4 years of age with 2 years of freshwater life and 2 of ocean life, but they can be from 3 to 8 years old with a complex combination of freshwater and ocean years.

Hoffman (1967) listed the following as parasites of the kokanee: protozoans (1), trematodes (3), cestodes (6), nematodes (3), acanthocephalans (2), molluscs (1), crustaceans (3). Bangham and Adams (1954) reported Myxosporidia and 6 species of cestodes, 4 of nematodes, 3 of trematodes, 2 of crustaceans, and 1 species of acanthocephalan from sockeye salmon and kokanee examined from 9 localities in British Columbia. Most of the fish examined were parasitized.

The parasites of the sockeye salmon are much better known and those of the marine adults were discussed in detail by Margolis and co-authors (1963, 1965, 1966). As far as the anadromous sockeye (in freshwater?), the flagellate *Cryptobia salmositica* was recorded from the sockeye (Katz et al. 1966), *Triaenophorus crassus* from smolts in Alaska (Margolis 1963, 1967a) and smolt infection by the cestode *Eubothrium salvelini* and the nematode *Philonema oncorhynchi* (Dombroski 1955). Hoffman listed the following parasites from *O. nerka*: fungi (1), protozoans (5), trematodes (8), cestodes (12), nematodes (6), acanthocephalans (4), molluscs (1), crustaceans (8). From *O. nerka kennerlyi* he listed the following parasites: protozoans (1), trematodes (3), cestodes (6), nematodes (3), acanthocephalans (2), crustaceans (3).

Apparently no natural hybrids are known, but Foerster (1935) gave results of artificial hybridization. Crossman and Buss (1966) reported the artificial hybrid of this species and the brook trout.

Relation to man Kokanee have long been sport fish of interest, at least at certain times of the year, in their natural range. They gained even more prominence when moved to areas where anglers did not have an abundance of other salmonids. They are often looked upon as difficult to catch when the angler learns they are plankton feeders. They are, however, rather readily taken fishing rather shallow with a flashy metal troll (willow leaf troll) of various patterns, with a small baited hook attached. Salmon eggs, maggots, and pieces of worm are the baits usually used. In certain areas they are at the surface in cool weather taking adult insects and can then be caught flyfishing. For their size, they provide good sport. The flesh is often blood-red, oily, and is delicious cooked in a variety of ways, or brined and hot-smoked.

They have apparently been commercially fished (200 per day by hook and line only) in Lake Pend Oreille, Idaho, since 1941. The average annual harvest there, by sport and commercial anglers, in 1951–1957 was estimated at over 1 million fish (Buss 1957). The fact that they can develop extremely large populations (14 tons were seined from Christina Lake, B.C., in a single night in 1898–1899) makes them both useful and potentially dangerous in exotic situations. Their introduction by the province of Ontario into lakes Huron and Ontario, starting in 1964, was successful in establishing a self-supporting population in Lake Huron but not in Lake Ontario. It was hoped that this plankton-eating species might utilize food resources now little used, provide a new sport fish and possibly a future commercial fish in these depleted lakes. An experimental introduction into Boulter Lake, Ont., has been successful and is providing a limited amount of very enjoyable angling. The original stock of these Ontario introductions were eggs taken from Kootenay Lake stream spawners at the Meadow Creek, B.C., egg station, eggs from Idaho, and eggs of shore-spawning stocks from Colorado, Montana, and Washington. The distribution is now being extended by eggs taken from large Lake Huron spawning runs in the Blue Jay and Manitou rivers, Manitoulin Island, now in their third spawning year. Adults are homing to the streams into which they were introduced, but there is a moderate amount of wandering. A 15-inch (381-mm) maturing kokanee was caught off Port Dover, Lake Erie. Those maturing in Lake Huron and Georgian Bay are averaging 15–17 inches (381–432 mm) in length and up to 2½ pounds in weight.

The sockeye salmon was long the mainstay of the Pacific salmon fishery. Its deep red flesh colour, rich flavour, high oil and protein content, uniform size and ease of mechanical handling in canneries all made it highly acceptable to the trade and on the market. It has always enjoyed the top price. It is caught largely by gillnetters working at the mouths of rivers, and purse seines at the south end of Vancouver Island. A small number are caught by trollers. Virtually all the catch is canned. It has long been the most important salmon in Alaska where it is called red salmon. The Fraser River in British Columbia, with all its nursery lakes, supports one of the chief groups of stocks of this species and these are exploited in inshore waters by Canada and the United States. The Adams River run of Fraser River sockeye is of tremendous value, has been extensively studied, and is probably known by fisheries biologists around the world. This exploitation has long required international agreement to govern the fishery, divide the catch, and provide for the passage upstream to various spawning grounds of adequate spawners to maintain the different stocks.

The British Columbia (= Canadian) catch of sockeye from 1951 to 1961 varied from a high of 12.04 million fish in 1958 (approximately half the total Canadian catch of all Pacific salmons in that year), to a low of 2.84 million fish in 1955. It runs on the average of 2–6 million fish per year (Kasahara 1963). In 1968 the British Columbia catch was a little over 41.2 million pounds, with a landed value just over 15.6 million dollars.

The sockeye is not an important sport fish but anglers have taken them in the Bristol Bay area of Alaska for many years. Sport and commercial fishermen have now developed lures which are effective for sockeye in the ocean, and are beginning to take them off the mouth of the Fraser River. In recent years British Columbia commercial trollers have taken very substantial catches with this new gear.

Nomenclature

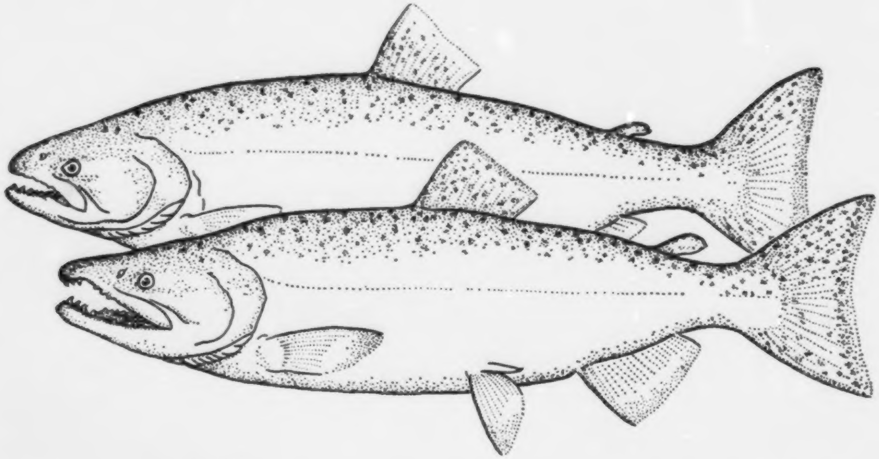
Salmo nerka — Walbaum 1792: 71 (type locality rivers and seas of Kamchatka, USSR)
Salmo paucidens (Richardson) — Richardson 1836: 222
Salmo Kennerlyi Suckley — Suckley 1862b: 307
Hypsifario kennerlyi — Gill 1863: 330
Oncorhynchus nerka kennerlyi — Bean 1891: 42
Oncorhynchus nerka (Walbaum) — Jordan and Evermann 1896–1900: 481

Etymology *Oncorhynchus* — hooked snout; *nerka* — Russian name for the anadromous form.

Common names Kokanee, kickininee, little redfish, land-locked sockeye, Kennerly's salmon, silver trout, yank. French common name: *kokani*; anadromous form — sockeye salmon, sockeye, red salmon, blueback salmon, blueback. French common name: *saumon nerka.*

CHINOOK SALMON

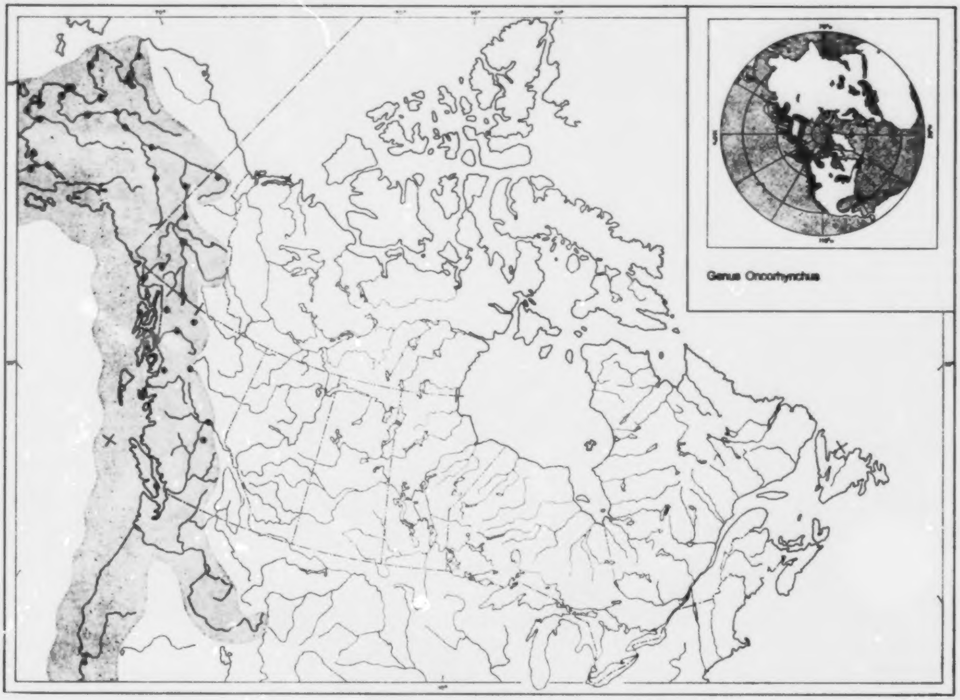
Oncorhynchus tshawytscha (Walbaum)



Description Body fusiform, streamlined, noticeably laterally compressed in large adults, the largest Pacific salmon, adult length variable but usually 33–36 inches (839–915 mm) in marine populations, and as much as 34¾ inches (882 mm) and, in the past, at least 30 pounds in the Great Lakes; body somewhat deeper than other species. Head approximately 20% of total length (longer in breeding males), conical; eye not large, position variable with sex and condition; snout rather blunt, greatly extended, narrowed, and turned down at tip in breeding males; mouth terminal, normally very little oblique, but greatly deformed in breeding males with lower jaw enlarged, turned up at tip, mouth unable to close; premaxillaries not protractile; maxillary extending well beyond eye, at least in adults; well-developed, moderately large, sharp teeth on both jaws, head and shaft of vomer, palatines, and tongue, none on basibranchials (= hyoids). Gill rakers rough, widely spaced, usually 16–26 with 10–16 on lower limb, 6–10 on upper limb. Branchiostegal rays 13–19. Fins: rather long, narrow, dorsal adipose present; dorsal 1, at centre of body, soft rayed, neither high nor long, edge square, usually 10–14 principal rays; caudal broad, emarginate to very shallowly forked, tips pointed; anal with long base, not particularly high, edge square, usually 14–19 principal rays; pelvics abdominal, not long, axillary process obvious, fin rounded, 10 or 11 rays; pectorals low, rather long, tip somewhat pointed, 14–17 rays. Scales small, cycloid, deeply embedded in breeding fish; lateral line complete, almost straight, 130–165 lateral line scales. Pyloric caeca 90–240. Vertebrae 67–75.

No nuptial tubercles but breeding males with more compressed body and head, prolonged, hooked snout, gaping mouth, enlarged more obvious teeth, embedded scales and colour change, female changes little. Freshwater stocks do not change as drastically as anadromous ones.

Colour As marine adults, back, top of head, and upper sides iridescent green to blue-green with gold flecking or sheen, sides below lateral line silvery, ventral surface silvery to white; back, top of head, upper sides, and all fins with at least a few black spots, both lobes of caudal fin spotted but more on dorsal lobe; lower gums black. Breeding fish are an overall olive-brown to



purple colour, males darker than females. Young have 6–12 parr marks, each longer and wider than other Pacific salmon, the lateral line passes through centre of most, dark area of parr marks equal to, or greater than, intervening light area. The adipose fin is pigmented at edge, clear in centre-front. There are no spots on dorsal fin. The first ray of the anal fin is elongate (less so than in coho salmon), white, but usually no black behind as in coho salmon.

Systematic notes Meristic characters have a broad range over the whole area of distribution, but are fairly uniform within stocks or races. Care should be taken in applying Pacific coast meristic values to the newly established Great Lakes populations. (*See* section entitled *Systematic notes*, coho salmon). Meristics of chinooks caught in Lake Ontario in 1970 are compared in the following table with those given for Pacific populations in the *Description* section.

	Lake Ontario	Pacific
Dorsal rays	11–12	10–14
Anal rays	14–16	14–19
Pelvic rays	10–11	10–11
Pectoral rays	14–15	14–17
Lateral line scales	130–137	130–165
Pyloric caeca	138–172	90–240

Distribution As marine adults this salmon occurs in the Pacific Ocean and, rarely, Arctic Ocean and in the Bering and Okhotsk seas and Sea of Japan. Young and spawning adults are found in most of the rivers flowing into these water bodies, from the Ventura River of southern California, north mainly to Point Hope, Alaska; and, as stragglers, east to Coppermine River (personal communication, J. G. Hunter), and in northeast Asia from northern Hokkaido to the Anadyr River. They ascend the Yukon River to its headwaters.

This species was the first Pacific salmon to be introduced elsewhere, and has probably been used more extensively in the past than any of the others. From 1872 to 1930 many attempts were made to establish California stock in the United States from Maine to South Carolina, as well as in Georgia, Louisiana, and Mississippi. It was also introduced in Mexico, Argentina, Chile, Nicaragua, England, Ireland, Holland, France, Germany, Italy, Hawaii, Australia, Tasmania, and New Zealand (Davidson and Hutchinson 1938). The only self-supporting anadromous populations that developed were on South Island, N.Z. Great Lakes populations in the past seemed to thrive initially but failed to maintain spawning populations.

A brief history of their introduction (California stock, at least prior to 1933) into the Great Lakes and elsewhere in Canada, and subsequent captures, is as follows:

Introductions 1873–1878 into Lake Erie by Michigan and Ohio; 1874–1881 into Lake Ontario from Newcastle, Ont., hatchery; 1881–1882 into Saint John River, N.B.; 1919–1925 into Lake Ontario (and Lake Huron?) by Ontario (and Michigan?); 1933 into Lake Erie, by Ohio; 1966 into Great Lakes by Michigan; 1969 into Lake Ontario by New York; 1971 into Great Lakes by Ontario.

Captures and Results 1876, 13–15-inch (330–381-mm) individuals, lakes Ontario and Erie; 1876–1881, to 32¾ inches (833 mm) and 14½ pounds, Lake Ontario, Ont.; 1921–1927, to 30 pounds in Lake Ontario, from Credit River to Napanee River, spawning runs of thousands in at least Credit River and Twelve Mile Creek, Halton County, Ont., one caught as far away as Georgian Bay near Killarney, Ont. (from Michigan?); 1935, commercial fishermen in Ohio catching 3–5 pound fish daily in Lake Erie, but probably both chinook and coho salmon, a chinook 19¼ inches (489 mm) caught near Kingsville, Ont.; 1939, 8½ miles off Saint John River, N.B. (from Maine?); 1940, 12½ pounds, Saint John River, N.B.; 1935 onward many reports from Great Lakes, probably all large rainbow trout, possibly including one said to have been caught in Georgian Bay, mounted, and now hanging in Georgian Hotel, Midland, Ont.; 1969, Nottawasaga River, Georgian Bay; 1970, small numbers, Bay of Quinte, Lake Ontario (from New York), 16.0–20.8 inches (406–530 mm). In September 1971, adults migrated up the Saugeen River from Lake Huron.

Biology (Details on anadromous stocks partly from Mason 1965; and Aro and Shepard 1967, those on a New Hampshire freshwater population from Hoover 1936.) Maturing chinook salmon move inshore into spawning rivers over most of the year. Many rivers have more than one run (spring to winter chinooks) each made up of fish bound for different spawning grounds (= stocks or races). The general trend is for runs to be earlier farther north, but they appear at the mouth of the Fraser River as early as January, reach maximum numbers in August and September, and are present to December in some years. Generally, the fish that appear at the river mouth earliest migrate farthest. There is the added complication of two varieties, known by flesh colour as red chinook and white chinook.

The adults proceed up river as short a distance as the point just above tidal influence, or as much as 600 miles in the Fraser River and over 1200 miles in the Yukon River. Spawning time varies with time of arrival, area, and length of river migration. In the Fraser River it is July to November, July and August in the Yukon River, August to September elsewhere on mainland British Columbia and October on Vancouver Island. In a freshwater population in New Hampshire, spawning took place from late September to early October. Chinook salmon generally spawn in larger rivers or larger tributaries, near riffles. They tend to spawn in deeper water and on larger gravel than the other Pacific salmon. The males and females are aggressive on the spawning grounds. The female digs the redd by lying on her side and thrashing the tail up and down. Freshwater populations may spawn in rivers flowing into the lake, or on gravel shoals in the lake. The redd or nest can be as much as 12 feet (3.66 m) long and 1 foot (305 mm) deep. Each female is attended by a larger, dominant male and often several smaller males. At spawning the female and the dominant male swim into the nest, the two fish approximate, their mouths gape, they vibrate, and eggs and sperm are released. The smaller males may dart into the nest and release sperm also. After spawning the female digs at the head of the nest and covers the eggs with gravel displaced in this way. The female may dig more than one redd and spawn with more than one male. Egg number varies with stock and size of female, but in Alaska, for females 28.7–39.8 inches (75.5–100.5 cm), it was from 4242 to 13,619, with an average of 8517. In the New Hampshire freshwater population, average egg number was 2500. The eggs are large, 6–7 mm in diameter, demersal, and orange-red in colour. The female guards the nest as long as she is able but the adults die, usually within a few days to 2 weeks. Precocious males have been known to live 5 months after spawning. Adults in New Hampshire, after spawning in a lake, migrated up tributaries and lived as long as a month, but the eggs failed to hatch.

Incubation of the eggs of anadromous stocks takes place with both ascending and descending temperatures, but eggs hatch in the following spring. The alevins spend 2–3 weeks in the nest while the yolk is absorbed, before struggling up through the gravel to become free-swimming, feeding fry. Some fry proceed almost directly to the sea but in many British Columbia stocks they remain in fresh water for a year, and those in the Yukon River, for 2 years. The fry in fresh water school at first but later become territorial and aggressive. At the end of their stay in fresh water they become smolts, their colour becomes silvery and in coastal populations they undergo preparations for the move to salt water. Migration to the sea takes place at different times. The smolts spend some time close to shore before moving to the open ocean or lake.

In Canada, most chinooks spend 2 or 3 years in the sea but adults migrating to the spawning rivers can be 2–9 years of age (Pritchard 1940), with only 1 year (jacks) or as many as 5 years at sea. Females are usually 4 or 5 years old. More northern populations spend a longer time at sea. Those in the New Hampshire lake matured at 3–5 years (mostly 4). Chinooks grow larger than the other Pacific salmons. Those usually seen are a maximum of 38 inches (968 mm) in length, and 30–40 pounds in weight. There is a record of an Alaskan chinook of 58 inches (147 cm) in length, and 126 pounds in weight. Another large chinook salmon caught in Alaska weighed 120 pounds, was 53½ inches (135.9 cm) long and 36½ inches (92.8 cm) in girth. The present angling record is 58½ inches (149 cm) in length, 36 inches (91.5 cm) girth, and 92 pounds in weight, caught in the Skeena River, B.C., in 1959. In reservoirs in California, chinooks were 3–5 pounds after 1 year, and 15–18 pounds after 3 years.

The only freshwater "habitat" of the anadromous stocks is the gravelly spawning stream or river. This species utilizes about 260 streams in British Columbia, fewer than do other species. About 50% of the production results from 14 streams or 5.5% of the streams used by this species for spawning. Upper lethal temperature (Brett 1952) for fry is 77.2° F (25.1° C) and preferred temperature 53.6°–57.2° F (12°–14° C).

The young in fresh water feed on terrestrial insects, Crustacea, chironomid larvae, pupae, and adults, corixids, caddisflies, mites, spiders, aphids, *Corethra* larvae, and ants. Obviously, food is taken at or above the water surface, in the water mass, and off the bottom. Even those spending a year or two in fresh water do not seem to utilize fish as food as do coho smolts in fresh water. Young in the sea close to shore feed on chironomid larvae and pupae. Fishes make up the bulk (to 97%) of the food of marine adults, and invertebrates such as squids, amphipods, shrimps, euphausiids, crab larvae, and other crustaceans make up the remainder (3%). Pritchard and Tester (1944) listed the following fishes as part of the food of marine adults: pilchard, herring, anchovy, capelin, surf smelt, eulachon, threespine stickleback, whiting, tomcod, grey cod, yellow shiner, sandfish, rockfish, wolf-eel. Herring and sand lance were the most frequently eaten fishes. Shad and smelt have been given as important foods of different landlocked populations, and growth is said to be poor in freshwater lakes lacking a pelagic forage fish.

Like the young of the other Pacific salmons, young chinook salmon in fresh water are preyed on by rainbow and cutthroat trouts, Dolly Varden, coho salmon smolts, squawfish, sculpins, mergansers, kingfishers, and other diving birds. Fry or smolts in the sea are probably taken by fishes, and birds when congregated at the river mouths. Adults at sea probably fall prey only to man, large mammals, and possibly the Pacific lamprey. Spawning adults are eaten by bears, other mammals, and the larger flesh-eating birds.

The young compete with other salmons and trouts for food, the marine adults with other fish-eating fishes, especially coho salmon, for food, and with most other salmonids for spawning grounds. Factors other than predation and competition associated with successful spawning, hatching, and migration to the sea, govern numbers of chinooks far more.

The parasites of the chinook salmon appear to be poorly known. Hoffman (1967) listed the following parasites: fungi (2), protozoans (9), trematodes (2), cestodes (5), nematodes (6), leeches (1), crustaceans (4), and molluscs (1). The presence of spores of the myxosporidian parasite *Henneguya salminicola* from this species as well as from the coho and pink salmons, was reported by Boyd and Tomlinson (1965).

Apparently a natural hybrid between the chinook and coho salmons is known. *See* Foerster (1935) for results of artificial hybridization.

Relation to man The chinook salmon has long been very important in the native food fishery and in the commercial and sport fisheries of the west coast. Its geographic importance may increase if recent introductions into the Great Lakes succeed. Capture and canning of chinook salmon, possibly the first full scale Pacific salmon fisheries, was underway in California in 1864.

The largest Canadian commercial catches of chinook salmon take place in southern British Columbia. Most of the catch (75%) is taken by trollers, but purse seines and gillnets are used also, and longlines and fish wheels are used elsewhere. The best troll catches are May to September. Between 1951 and 1961 catches in British Columbia ranged from a high of 1.06 million fish in 1958 to a low of 685,300 in 1961. An all-time high catch of 1.74 million fish took place in 1934 (Kasahara 1963). The British Columbia catch in 1968 was 13.6 million pounds, worth over 6.8 million dollars. Much of the troll catch is sold fresh, fresh-frozen or canned, the net catches are canned. Alone among Pacific salmon, the flesh of this species is regularly either red or white and the red commands the higher price. Some white coho has been reported but it is rare.

Chinook salmon are often called "tyee" by anglers and there is a fishing club by that name in Campbell River, B.C., members of which come from far and wide to fish for this species. On the whole, chinook caught by anglers are smaller than those caught by commercial fishermen but individuals of 50–70 pounds are not rare. Most of the angling was between Vancouver and Victoria, Nanaimo, Cowichan Bay, and Campbell River, but now most of the Strait of Georgia is used by Canadian and United States anglers. Anglers catch, per year, about 59,000 chinook over 2 years of age, and about 35,000 grilse (= coho and chinook). The adult catch has been as high as 93,000 in one year. Chinook are taken to a lesser extent in fresh water also. Plugs, spoons, and live or dead herring are trolled rather deep for this species, and live, salted, or fresh-cut herring are used as bait for still fishing in moderately deep water. The potential size is the main attraction, but the flesh is highly prized also. The commercial and sport fisheries for this species were summarized by Kasahara (1963), Milne (1964), and Tuomi (1964).

Establishing this voracious, fish-eating but non-reproducing species in the fresh waters of New Hampshire led to the interesting suggestion of using it in fresh water for control of coarse fish. The chinooks exterminated smelt from a lake in 3 years and then died out themselves, leaving the lake ready for the re-introduction of native trout.

Nomenclature

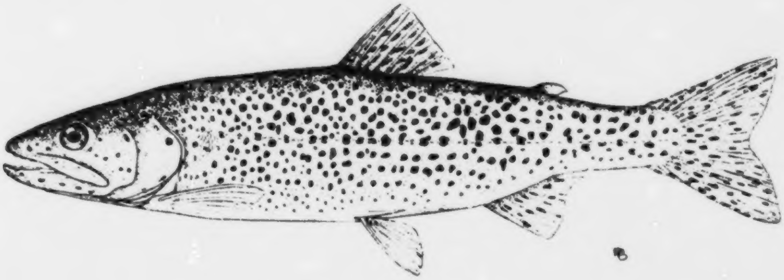
Salmo tschawytscha	— Walbaum 1792: 71 (type locality rivers of Kamchatka, USSR)
Salmo quinnat	— Richardson 1836: 219
Salmo warreni Suckley	— Suckley 1862b: 308
Salmo richardii Suckley	— Suckley 1862b: 311
Salmo cooperi Suckley	— Suckley 1862b: 312
Oncorhynchus Cooperi	— Suckley 1862b: 313
Oncorhynchus chouicha	— Bean 1894a: 26
Oncorhynchus tschawytscha (Walbaum)	— Jordan and Evermann 1896–1900: 479
Oncorhynchus tshawytscha (Walbaum)	— Clemens and Wilby 1946: 85

Etymology *Oncorhynchus* — hooked snout; *tshawytscha* — vernacular name of this species in Kamchatka.

Common names Chinook salmon, spring salmon, king salmon, tyee, spring, chinook, king, quinnat. French common name: *saumon chinook.*

CUTTHROAT TROUT

Salmo clarki Richardson



Two forms of this species are regularly recognized in Canada, the coastal cutthroat trout and the Yellowstone cutthroat trout. There is great variability of all characters including those usually used to separate the two forms. It is difficult to separate them other than on the basis of their location. Non-anadromous populations occur even in the area of the anadromous coastal form. Therefore, the two forms are treated here together.

Description Body typically troutlike, elongate, average length 12–15 inches (305–381 mm), body rather rounded to moderately compressed, greatest depth at dorsal fin usually only moderate, about equal to head length, body rather deep in large adults of some populations. Head short, conical, length equal to body depth; eye moderate, about 22% of head length; snout somewhat pointed to rounded, slightly greater than eye diameter, more so in spawning males; mouth terminal, little oblique, rather large; maxillary long, at least to posterior margin of eye, often far beyond; teeth well developed on upper and lower jaws (premaxillary, maxillary to near tip, dentary), head and shaft of vomer, palatines (narrow space between anterior vomerine and palatine teeth), 2 rows on tongue, 2–20 teeth on basibranchials or hyoids, often difficult to see or obsolete. Gill rakers 14–22, usually 7 on upper limb, 11 or 12 on lower limb. Branchiostegal rays usually 10–12. Fins: dorsal adipose present, dorsal 1, soft rayed, 8–11 principal rays (10–13 total rays); caudal shallowly forked; anal with 8–12 principal rays (11–13 total rays), tip pointed to rounded, edge square to emarginate; pelvic rays 9 or 10; a distinct pelvic axillary process present; pectoral rays 12–15. Scales cycloid, small to medium in size (*see* Vernon and McMynn 1957, for scale characteristics and comparison with rainbow trout), 116–230 scales in lateral line (usually 120–180 slightly larger ones in anadromous populations); lateral line complete, decurved at front and then straight. Pyloric caeca 27–57. Vertebrae usually 60–64. (*See also* Miller 1950b; Qadri 1959; Clemens and Wilby 1961; Carl et al. 1967 for characters to separate coastal and inland stocks.)

No nuptial tubercles, but, in breeding males, kype slightly developed in anadromous populations and lower jaw appears extremely long.

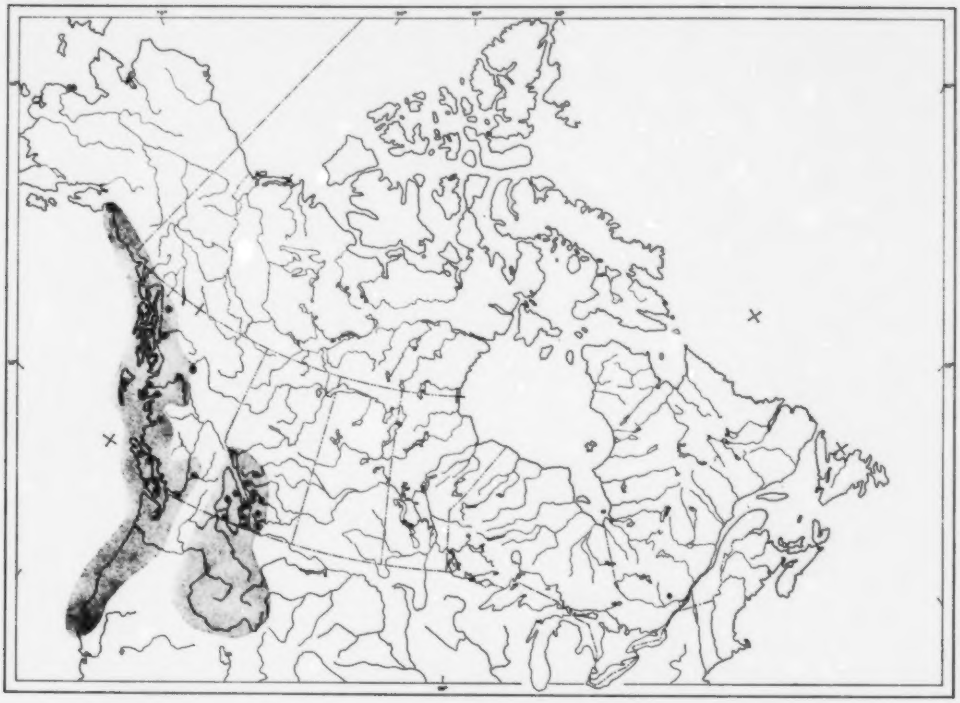
Colour This species shows a bewildering array of colours and pigment patterns, different from watershed to watershed and between the anadromous and inland stocks. This has been further complicated by cross transplantation of the two main stocks in British Columbia and elsewhere on the Pacific coast. One of the main colour characters usually used to distinguish this species from other blackspotted trout are two yellow or orange to red lines in the skin folds of each side of the lower jaw, from which the common name is derived. These are variable in size and intensity, faint in young, and faint to absent in individuals in the sea or recently migrated from the sea.

Coastal form Body dark green above, olive-green on sides, silvery below, pink sheen on gill covers, black spots on back and side numerous, usually extending well below the lateral line, those below the lateral line about equal in number on front and back halves of body; rounded spots on dorsal, caudal, usually on anal and bases of paired fins; several on adipose fin, edge of adipose fin usually not a complete black border; fins usually uniform in colour, without coloured borders. Fish in sea, or newly migrated from sea, more blue, sides silvery, spots less conspicuous.

Interior form (= Yellowstone cutthroat) Body yellow-green with red on sides of head, front of body, and on belly at all times or in spawning fish; spotting variable but spots below lateral line are closer and more numerous on the posterior half of the body than on the anterior half; spots on dorsal, adipose, and caudal fins, anal and paired fins without spots; at times a narrow pink streak, not a broad pink band, along sides. Colours intensify in spawning males. *See* colour illustrations of various stocks or forms in Dymond (1932c) and Paetz and Nelson (1970). Qadri (1959) included photographs of specimens of both stocks or subspecies with both types of supposedly characteristic spotting.

Young of both forms with about 10 oval parr marks on lateral line, overlaid except in smallest, with fine black spots; at times up to five dark ovals on back, dorsal fin often with dark leading edge, sometimes small patches of white on dorsal and anal fins, a few black spots on adipose fin, red to yellow hyoid marks visible on individuals over 3 inches (76 mm) in length.

Systematic notes The coastal form alone was originally described as *Salmo clarki*, the interior form was described later as *Salmo lewisi*, and the two forms were later reduced to the subspecies recognized today. *See* Qadri (1959) for details of subspecies distinction, and Hartman (1956) for taxonomy of the coastal form. As a result of the bewildering tendency to develop different colour and spotting patterns in different



southern rivers, populations in many rivers were, at one time, known by separate subspecies names. Many of these semidistinct forms are still known by common names involving watershed or regional designations. Miller (1950b) listed 11 such combinations. The cutthroat was long known as *Salmo mykiss* and thought to be part of a form by that name which occurs on Kamchatka. It may be closely related. Several early descriptions of the cutthroat by that name are confusing combinations of cutthroat and rainbow trouts. In 1931, Dymond described from isolated, alpine situations in British Columbia, a form he called *S. c. alpestris*. The few characteristics by which this form differed are now thought to be the result only of its unique isolated habitat, as is the case with most of the more southern forms. The general situation has been still further confused by natural hybridization with rainbow trout planted in the range of the interior form, by the introduction of cultured hybrids of the rainbow and cutthroat trouts (called "Cranbrook trout"), by the transfer of the coastal and interior forms into each other's region and the resulting intergradation of the two forms in both areas. Simon and Dollar (1963) treated cytological concepts of speciation and systematics.

The cutthroat trout is known to hybridize with the rainbow trout and with the golden trout. The two subspecific forms intergrade readily. All of these are apparently fertile combinations.

Distribution The cutthroat trout occurs in fresh, brackish or salt water, in North America mostly west of the Rocky Mountains. Its distribution extends from the Eel River in northern California to Seward, southeastern Alaska, on the coast, and penetrates as far inland as central Colorado and northwestern New Mexico.

In Canada the coastal and Yellowstone varieties are separated by a central area in which the rainbow trout occurs. The inland form occurs in western Alberta in the headwaters of river systems from the Milk to the Athabasca (native and introduced), west as far as the Arrow Lakes (Columbia River), and Shuswap Lake (Fraser River), B.C. It is absent from the Okanagan River system. The coastal form occurs as far inland in the south as a line from Hope, B.C., to the Thompson River near Ashcroft, B.C., and to Babine Lake in the north.

It has been extensively introduced within this natural range. About 1942, it was introduced in Laurentian lakes in Quebec. It succeeded but began to appear in the fishermen's catches only in 1966.

In Alberta there are four blackspotted trouts of the genus *Salmo*. In addition to the two native species, the cutthroat and rainbow trouts, there is the introduced brown trout and the exotic golden trout, *Salmo aguabonita* Jordan. This species, whose native distribution is basically in lakes above 10,000 feet altitude in the Kern River drainage of the Sierra Nevada Mountains of California, was introduced into high altitude lakes (South Fork, Three Isle, Gap, and Galatea) in southwestern Alberta in 1959. At least one fish, of 4 pounds 7 ounces, has been taken from South Fork Lake (Paetz and Nelson 1970).

Biology Adult anadromous cutthroat return to freshwater spawning streams in late autumn and early winter. Ripe individuals are found in the Cowichan River, Vancouver Island, as early as November but spawning apparently takes place there in February and March. Elsewhere it is February to May. The Yellowstone cutthroat spawns in spring and early summer about 3–5 weeks after ice breakup, when the water temperature is near 50° F (10° C). In both forms spawning apparently takes place only in small, gravelly streams. On the spawning grounds the males court the females (nudging and quivering) and are aggressive toward other males. Males or females will drive off a female that attempts to dig too close to a redd being dug or spawned in. The female prepares a redd by lying on her side and thrashing the tail up and down so as to create a depression in clean gravel. This is usually at least 1 foot (305 mm) in diameter and 4–5 inches (102–127 mm) deep. When digging is completed, the female settles into the nest, head and tail curved upward, the male swims to her side, the fish gape, become rigid, vibrate, and sperm and eggs are released. The eggs fall into the spaces between the gravel in the bottom of the redd. Other males may take part in the spawning act also. After spawning the female digs at the upstream edge of the nest covering the eggs with as much as 6–8 inches (152–203 mm) of displaced gravel. Females often dig more than one redd and may spawn with more than one male. Males often spawn with more than one female. Spawning takes place during the day or night. Smith (1941) gave a detailed description (and photographs) of spawning from which these details have been taken. Over the whole distribution, reported egg number per female ranges from 226 to 4420 for females 7.9–17.1 inches (202–434 mm) total length. It is often higher in fish of equal size spawning for the first time as compared to the second time, and is not necessarily higher in one subspecies than in the other (Carlander 1969). Average egg number per female, disregarding size and location, would be 1100–1700. Eggs are usually 4.3–5.1 mm in diameter, orange-red in colour, demersal and adhesive at least at first.

There is a high mortality of adults in the spawning runs of many populations and a high egg mortality in the redds. The eggs usually hatch in 6–7 weeks and the alevins remain in the redd for another 1 or 2 weeks. With the different spawning times, fry emergence can be from April in coastal populations to August in Yellowstone populations. In some areas fry move directly out of the small streams into the larger river or into a lake. Even in the coastal area, some fish remain in fresh water at all times whereas others may go to sea very soon, or go to sea for the first time at about 5 inches (127 mm) length in the second or third year. The migration to the river, lake, or sea is usually in the spring, and may coincide with that of Pacific salmons, leading to heavy predation on the salmon. Some may spend as much as 4 years in creeks before migrating to a lake. Those of the coastal form which move down river to the sea usually remain within the influence of the river or go only a very short distance to sea. They stay in the estuaries, often moving into the streams in spring to feed when young salmon are migrating. Individuals may remain in the sea for one or more years and each year some move into their spawning stream in fall and winter in preparation for spawning.

Growth and potential maximum size of this species varies from stock to stock, and between the sea-run coastal form and the inland form in Canada. Carlander (1969) gave an extensive summary of age–length relation indicating area, altitude, and habitat. He also discussed factors governing growth. Accurate age determination of cutthroat trout from high, cold habitats is often made difficult by the fact that some fish pass the first winter without scales and have no annulus at the end of the first growing season. Cooper (1970) gave details on scale development and growth of cutthroat on Vancouver Island. The following table gives the age–length relation (and age–weight in British Columbia) for a Vancouver Island coastal population and for the type locality of the Yellowstone subspecies.

The coastal subspecies apparently has non-anadromous stocks which grow to 30 inches (762 mm) and 17 pounds in British Columbia. The sea-going fish range from 1½ to 4 pounds. The interior type is usually about 12 inches (305 mm) long and about one pound weight but grow to be as heavy as 10 pounds. Carlander (1969) listed this species to lengths of 39.1 inches (991 mm) and weight of 41 pounds, which is probably the fish listed as the angler record. It was caught in Pyramid Lake, Nev., in 1925. Sexual maturity is reached by males as early as 2 years of age and by females as late as 5 or 6. The average age at first spawning is 2–4 years. Many cutthroat live only a few years, will not spawn more than once, and there may be 2 years between spawning. Ten years would appear to be maximum life expectancy but 4–7 is more common.

The habitat of the cutthroat trout consists of gravelly, lowland, coastal streams and lakes, inland alpine lakes and small rivers, and estuaries or the sea near shore. They occur in lakes and streams over 8000 feet altitude. The young, whether of the anadromous or inland stock, spend their early life in the gravelly spawning streams. Not all populations within the range of the coastal subspecies go to sea, some spend their whole life in fresh water. Hartman and Gill (1968) studied habitat relation of cutthroat trout and steelhead in British Columbia. They found that cutthroat were usually in smaller tributaries and headwaters, and in streams of smaller drainage areas which ran through sloughs rather than dropped directly to the sea. In some areas individuals of stream-resident populations have a home territory, usually a gravelly pool, limited to as little as 20 yards (18.3 m) in which they spend the whole of their life (Miller 1957).

Food of this species consists mainly of insects, both aquatic and terrestrial, but small fishes form an important part, at least at times. Other food items include various plankton crustaceans, crayfish, salmon eggs, and dead salmon. Midges, other dipterous flies, mayflies, caddisflies, and beetles enter the diet. The young start feeding 14–23 days after hatching and the food is at first all small invertebrates. Fry and older fish in rivers and lakes feed mostly on fishes, at times almost exclusively migrating salmons. Examination

		Age (*years*)						
		1+	2+	3+	4+	5+	6+	7+
	FL							
Buttle L., Vancouver Is., B.C.	*inches*	**8.7**	**12.9**	**14.3**	**15.6**	**16.1**	–	–
(McMynn and Larkin 1953)	*mm*	**221**	**328**	**363**	**396**	**409**	–	–
	Wt (*oz*)	**3.9**	**12.5**	**16.9**	**20.5**	**21.2**	–	–
	TL (calculated)							
Yellowstone L., Wyo.	*inches*	**1.8**	**5.1**	**8.9**	**12.3**	**15.5**	**17.5**	**19.1**
(Bulkley 1961)	*mm*	**46**	**129**	**225**	**312**	**393**	**444**	**485**

of stomachs at other times showed that 78.3% of the cutthroat had eaten fishes such as salmon, trout, sculpin, and stickleback. Of the fishes eaten then, coarse fishes made up over 55% and possibly 62%. In general, the sticklebacks were most often eaten (Idyll 1942). Cutthroat trout consume large quantities of fry and yearling sockeye salmon in Cultus Lake, B.C. (and other salmons elsewhere), and have been looked upon as its main predator there. Detailed analysis of the food of this species elsewhere was given by Hazzard and Madsen (1933) and Dimick and Mote (1934).

Very little is known of the predators of this species. Coho salmon smolts, other cutthroat trout, rainbow trout, and squawfish probably prey on the young. In certain southern, inland areas, the white pelican is a serious predator, so other aquatic and predaceous birds may be also. In various areas food habits lead to competition between cutthroat trout and such species as brook trout, other trouts and salmon, longnose sucker, redside shiner, and speckled dace. Hatchery-reared cutthroat trout compete poorly for space and food with wild cutthroat trout and did not do well when released in Alberta streams containing wild fish (Miller 1954).

Bangham and Adams (1954) examined 179 specimens of *S. clarki* from 11 locations in British Columbia and reported all specimens with one exception were infected with parasites. They stated that 64% of the trout carried the trematode *Crepidostomum farionis*, 57% the nematode *Metabronema salvelini*, 35% the acanthocephalan *Neoechinorhynchus rutili*, and 32% the cestode *Proteocephalus salmonidicola*, these being the principal parasites. Black-spot was also reported by the authors. In all, 18 species of parasites were identified.

See Cope (1964) for a list of publications on the parasites of this species in Yellowstone Lake, Wyo., and Davis (1953) for diseases of the cutthroat trout.

Hoffman (1967) listed the following parasites for the cutthroat trout over all of its North American range: protozoans (5), trematodes (14), cestodes (10), nematodes (16), acanthocephalans (3), leeches (2), molluscs (1), crustaceans (4).

Relation to man The cutthroat trout is an important sportfish where it occurs in Canada. Most anglers, however, consider it inferior in sporting quality to the steelhead and Kamloops varieties of the rainbow trout. It is a hard fighter, can be large, but does not leap and thrash as much as a rainbow does. This species will strike a wide selection of lures including flies (wet flies best), small spoons, spinners, and plugs, and live bait (where permitted). Cutthroat provide good river fishing in areas where other trout may be in the lakes. Best angling success in lakes is usually during the mayfly hatches of July to September. Often best catches are in the rivers earlier than this. The sport fishery for cutthroat trout in Lakelse Lake, B.C., was discussed by Bilton and Shepard (1955). Angler success there has in the past, varied from 0.6–1.4 fish/man-hour in the river and 0.9–1.9 in the lake. Several reports on angling for the Yellowstone variety in the United States were listed by Cope (1964).

Cutthroat trout are raised commercially in southwestern United States but probably mainly for introduction into private ponds rather than use as food as is the case in many rainbow trout farms.

The flesh is orange-red, rich, and of excellent flavour smoked, fried, or, in the case of large individuals, baked.

Nomenclature

Salmo Clarkii (Richardson) — Richardson 1836: 225 (type locality Cathlapooth River, Wash.)
Fario stellatus — Girard 1857b: 219
Fario clarkii — Girard 1857b: 219
Salmo purpuratus — Günther 1866: 116

Salmo brevicauda Suckley — Suckley 1862b: 308
Salmo lewisi — Suckley 1874: 139
Salmo mykiss Walbaum — Eigenmann 1895: 115
Salmo clarkii alpestris — Dymond 1931b: 394
Salmo clarkii Richardson — Dymond 1932c: 27
Salmo clarkii clarkii Richardson — Dymond 1932c: 28
Salmo clarkii lewisi (Girard) — Dymond 1932c: 30
Salmo clarki clarki Richardson — Scott 1958: 6
Salmo clarki lewisi (Girard) — Scott 1958: 6

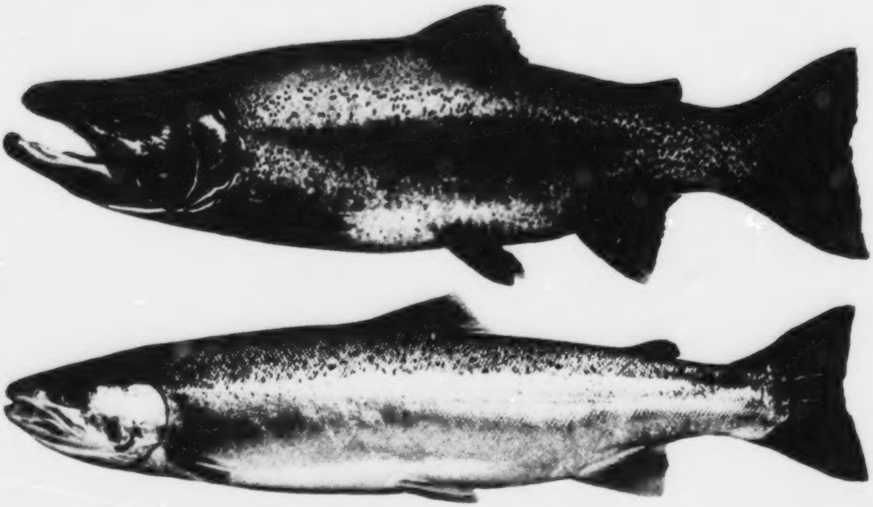
No real attempt has been made to trace the many changes of single *i* and double *i* endings nor in the use of species and subspecies.

Etymology *Salmo* — Latin name for the salmon of the Atlantic; *clarki* and *lewisi* — Captains William Clark and Meriwether Lewis, leaders of the Lewis and Clark expedition.

Common names Cutthroat trout, coastal cutthroat, Yellowstone cutthroat, coastal cut-throat trout, red-throated trout, Clark's trout, lake trout, sea trout, short-tailed trout. French common name: *truite fardée*.

RAINBOW TROUT, KAMLOOPS TROUT, STEELHEAD TROUT

Salmo gairdneri Richardson



Upper photo, *rainbow trout*; lower photo, *steelhead trout*.

Description Body troutlike, elongate, average length of rainbows and Kamloops 12–18 inches (305–457 mm), steelhead 20–30 inches (508–762 mm), body somewhat compressed especially in larger fish and all steelhead; body depth variable with area and size. Head length about 20% of total length, but variable with sexual maturity in males, especially steelhead; eye moderate, usually about 20% of head length; snout rounded, length only slightly greater than eye diameter except in breeding males when it is extended and lower jaw is turned up; mouth terminal, only slightly oblique, rather large; premaxillaries not protractile; maxillary long, usually passing eye; well-developed teeth on both jaws (premaxillary, maxillary, dentary), on head and shaft of vomer, palatines, tongue, no teeth on basibranchials (= hyoids). Gill rakers moderate, 16–22, usually 6–9 on upper limb, 11–13 on lower limb. Branchiostegal rays 9–13, often different number on each side. Fins: dorsal adipose present; dorsal 1, at midpoint of body, neither high nor long, soft rayed, 10–12 principal rays, edge square; caudal broad but not long, moderately forked, rather square in large individuals; anal neither long nor high, edge square, 8–12 principal rays; pelvics abdominal, rather small, square to rounded, 9 or 10 rays, small axillary process present; pectorals not long, rounded to rather pointed, 11–17 rays. Scales cycloid, rather small but variable with different stocks (*see* Vernon and McMynn 1957); lateral line complete, slightly curved anteriorly, 100–150 pored lateral line scales. Pyloric caeca 27–80 (*see* Northcote and Paterson 1960, for relation of caeca number to fish size). Vertebrae 60–66 (*see* Garside 1966, for effect of rate of development on number).

No nuptial tubercles but minor changes to head, mouth, and colour especially in spawning males.

For bewildering variability in body proportions with size, and in number of parts, over the whole range of the species, between stocks, and with changing environmental conditions, *see* Mottley (1936b), Needham and Gard (1959), Bidgood and Berst (1967), MacCrimmon and Kwain (1969).

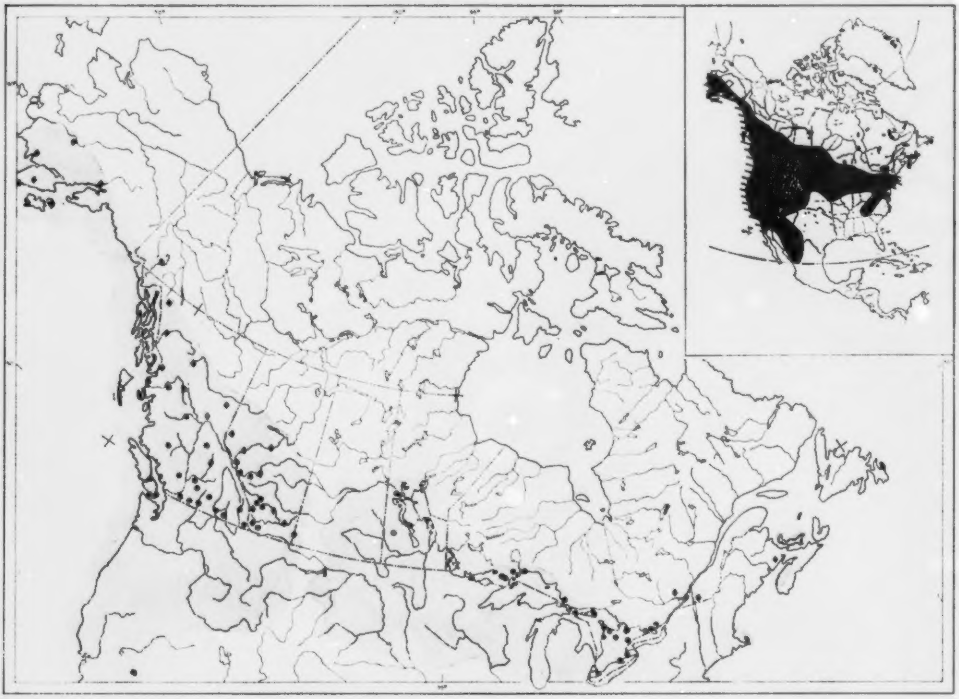
Colour Variable with habitat, size, and sexual condition. Stream residents and spawners darker, colours more intense, lake residents lighter, brighter, more silvery. Different colour types often called by different names by anglers — darker stream fish often called rainbows; brighter, silvery fish in small lakes often called Kamloops trout; large silvery specimens returning from the sea and in Great Lakes or tributaries called steelhead. Back, top of head, and upper sides steel-blue, blue-green, yellow-green to almost brown; sides silvery, white, or pale yellow-green to grey; underparts silvery, white, or grey to yellowish. Cheeks and opercula are pink, the body sides marked with a vague, pink blush to wide rose to red band and a large number of rather small black spots, mostly restricted above the lateral line or scattered over whole side. Dorsal and caudal fins with regular or radiating rows of black spots, adipose fin with black border and a few spots, other fins with a few spots, dusky, or immaculate. Skin folds of undersurface of lower jaw in certain areas with faint, red lines causing confusion with cutthroat trout. Spawners and spawned-out fish recently returned to the lakes (often called kelts) are very dark, often referred to as dirty, and the lateral band is very red. Stream residents often retain parr marks into adult stage and appear quite different from lake residents of comparable age and size.

The young are blue to green on the dorsal surface, silver to white on the sides, and white below. There are 5–10 dark marks on the back between the head and dorsal fin. There are 5–10 short, dark, oval parr marks widely spaced on the sides, straddling the lateral line, the space between adjacent parr marks wider than a parr mark; some small dark spots above but not below lateral line. The dorsal fin has a white to orange tip and a dark leading edge, or a series of bars or spots; the adipose fin is edged with black, the anal fin has an orange to white tip, and there are few or no black spots on the caudal fin (McPhail and Lindsey 1970).

Systematic notes Like the cutthroat trout, this is a very plastic species that differs considerably over the whole of its range. Populations in different watersheds were long called by different scientific names and still by different regional common names in the south. The various forms in Canada have, from time to time, been referred to as separate species, as distinct subspecies, and as only races, stocks, or variants of a single species. There is still argument as to the relation of this species and such black-spotted forms as *Salmo gilae*, the gila trout, *Salmo aguabonita*, the golden trout of California, and *Salmo mykiss* of Asia, which are still recognized as separate species. The golden trout has been introduced in Alberta and may lead to confusion there.

Richardson's original description of *Salmo gairdneri* in 1836 was a steelhead, that of Jordan in 1892, as *Oncorhynchus Kamloops*, was an inland lake form. Dymond in 1931 described an alpine form as *S. kamloops whitehousei*. It was later considered another of the habitat variables that are not really distinct. Other common synonyms in use in Canada as species or subspecies (*see Nomenclature* section) were *irideus*, *rivularis*, *purpuratus*, *stellatus*, and *argentatus*. Since this species is so variable, Needham and Gard (1959) suggested there was no utility in subspecies names. There is, however, some utility in use, at least by anglers, of the separate common names rainbow trout, Kamloops trout, and steelhead or steelhead trout. Confusion does arise here, however, as steelhead is a term usually restricted to large, west coast, sea-run fish. The stock originally introduced into the Great Lakes was steelhead and the purely freshwater stocks retain a life history pattern which utilizes these large lakes as they originally did the sea.

See also Mottley (1934, 1936a), Miller (1950b), Hartman (1956), Behnke (1966), and Northcote et al. (1970).



The rainbow trout is known to hybridize in nature with the cutthroat trout, and various interesting and colourful, artificial hybrids with other species were described by Buss and Wright (1956).

Distribution The native range of the rainbow trout (including all varieties) was the eastern Pacific Ocean and the fresh water, mainly west of the Rocky Mountains, from northwest Mexico (including extreme northern Baja California), to the Kuskokwim River, Alaska. It is probably native in the drainages of the Peace and Athabasca rivers east of the Rocky Mountains. This species, under all its names, has been so widely introduced in North America outside its natural range as to suggest it occurs throughout the United States in all suitable localities. A New York State introduction of 1874 is possibly the earliest. It has also been introduced into New Zealand, Australia and Tasmania, South America, Africa, Japan, southern Asia, Europe, and Hawaii. *See* MacCrimmon (1971) for details of world distribution and introductions.

In Canada, it occurs outside British Columbia from the Avalon Peninsula of Newfoundland, across the southern portions of the provinces from Nova Scotia to Ontario, north to central Manitoba (and central Saskatchewan?), to northern Alberta, and in the Yukon Territory (McPhail and Lindsey 1970). This species apparently occurs naturally in the Alsek River, Yuk., and was also introduced near Whitehorse, Dawson, and Mayo. The distribution map shows a wavy line in Saskatchewan and in the United States which is intended to indicate that occurrence west and south is of a scattered and indefinite nature and usually supported only by constant hatchery introductions.

Some dates of first introduction in Canada are: Newfoundland 1887; New Brunswick and Nova Scotia 1899; Prince Edward Island 1925; Great Lakes 1895; Ontario at least by

1904 and possibly as early as 1883; Manitoba 1938; Saskatchewan 1924; Alberta 1958; Yukon Territory 1943.

Biology Various life history factors of this species are extremely variable depending on location, type, and habitat. A river system in British Columbia could contain river-resident rainbow trout, early migrating (winter-run) steelhead spending 3–4 months there, late migrating (summer-run) steelhead spending 9–12 months there, and lake resident Kamloops trout. Each of these populations could have different life history characteristics. Even though anadromous steelhead spend a considerable part of their time in fresh water and are usually a sport fish only there, they will be treated here only superficially. For extensive life history information on anadromous steelhead *see* Shapovalov and Taft (1954), Maher and Larkin (1955), Withler (1966).

The situation is not made simpler by excluding anadromous steelhead, as the stocks of this species introduced into the Great Lakes were, in the main, steelheads. They utilize these large lakes as seas, their biology is somewhat different and they are often referred to as steelhead in the literature and by anglers. We will not make this distinction here.

Rainbow trout are basically spring spawners. They spawn in smaller tributaries of their rivers, or inlet or outlet streams of their lakes, from March to August but mainly from mid-April to late June (Lindsey et al. 1959; Hartman et al. 1962). Spawners in some areas move toward the spawning stream while ice is on the lake. The usual site chosen is a bed of fine gravel in a riffle above a pool. Unlike the chars, there is little evidence that rainbow trout can be successful spawning on beaches of lakes that do not have rivers flowing into them. Great Lakes populations enter some spawning streams from late October to early May and spawn from late December to late April (Dodge and MacCrimmon 1970). Some rainbow trout in California may spawn twice a year (Hume 1955).

Spawning temperature is usually between 50° and 60° F (10.0°–15.5° C). Males are aggressive on the spawning grounds and drive other males away from a nest occupied by a female. The male courts the digging female by sliding along and crossing over her body, rubbing his snout against her caudal peduncle, by body vibrations, and body pressing. Each digging female is usually attended by more than one male but a larger one is dominant and more active in courtship. The female digs a redd in the gravel by turning on her side and beating her tail up and down. In this way she cleans the gravel and excavates a pit that is longer and deeper than her body. Nest building takes place day and night. When ready to spawn, the female rests near the bottom of the centre of the nest, the dominant male quickly moves in to a position parallel to her, the bodies are pressed close together, both fish gape, arch the body, vibrate, and the eggs and milt are released over a few seconds. Often two males participate with a single female in one spawning. The eggs fall into spaces between the gravel. Immediately the female begins digging at the upstream edge of the nest and the eggs are covered by the displaced gravel.

Females dig and spawn in several nests with the same male or other males, depositing as many as 800–1000 eggs in each redd. Egg number per female in interior British Columbia has been given as 1366–2670, and as averages of 4083 and 4422. Egg number may be as low as 200, and as high as 12,749 in certain selected broodstocks elsewhere. Starved fish have considerably fewer mature, viable eggs (Scott 1962). The eggs are 3–5 mm in diameter, demersal, and pink to orange in colour.

Eggs usually hatch in approximately 4–7 weeks and alevins take an additional 3–7 days to absorb the yolk before becoming free swimming. However, time of hatching varies greatly with region, habitat, and type, as a result of vastly different spawning times and temperature history after egg laying. Early development of eggs and alevins was given in detail by Wales (1941) and Knight (1963). The fry commence feeding about 15 days after hatching. Fry are usually seen emerging from the nests from mid-June to mid-August when spawning is in April or May. The fry of lake-resident spawners move up or down the spawning river to the lake almost immediately or by autumn, or they may spend as much as 1–3 years in the streams. Those of stream-resident spawners remain in the streams and those of steelhead migrate to the sea, usually after 2 years (1–4) in fresh water.

Growth can only be described as bewilderingly variable with area, habitat, life history type, and quantity and type of food. Ages can be determined from the scales and the scale diameter × body length relation is close enough to direct proportionality for back calculations (Smith 1955). The following tables give age–length and age–weight relations for several populations across Canada and compare an anadromous steelhead population with a population of rainbow trout from the Great Lakes.

See also Larkin et al. (1957), for a summary of average size at various ages for many different types of lakes in British Columbia.

As with all other factors, the growth history differs from one population to another. Length of time spent as young in the spawning stream, length of time spent at sea or in a lake, and number of years before first spawning, can vary with different individuals in the same population and influence potential size (*see* bottom part of table below). Individuals returning to spawn in a Lake Huron stream were mostly 5 years of age but ages 3–7 were represented. The males

		Age						
		1	2	3	4	5	6	7
L. Simcoe, Ont.	TL							
(McCrimmon 1956)	*inches*	4.0	7.5	16.5	22.0	26.0	28.5	31.5
	mm	102	190	419	559	660	724	800
Pyramid L., Alta.	FL							
(Rawson and	*inches*	2.4	5.3	7.5	9.3	11.6	14.8	17.9
Elsey 1950)	*mm*	61	135	190	236	295	376	455
	Wt (*oz*)	0.8	1.5	3.0	5.6	11.3	21.6	38.0
Kootenay L., B.C.	FL							
(Cartwright 1961)	*inches*	2.4	4.9	11.4	17.5	23.6	30.8	–
	mm	62	125	289	445	598	785	–
L. Okanagan, B.C.	TL							
(Clemens et al. 1939)	*inches*	2.6	4.7	11.4	17.1	20.3	23.2	28.0
	mm	65	120	290	435	515	590	710
	Wt (*lb*)	0.1	0.3	1.0	3.0	4.5	8.0	12.0
Buttle L.,	FL							
Vancouver Is., B.C.	*inches*	–	10.0	10.5	11.5	12.4	–	–
(McMynn and Larkin	*mm*	–	254	267	292	315	–	–
1953)	Wt (*oz*)	–	5.6	7.3	8.6	9.8	–	–

Years in ocean (or lake)		1				2			3				4	
Years in fresh water (or stream)		1	2	3	4	1	2	3	1	2	3	4	2	3
	FL													
Nottawasaga R.,	*inches*	–	18.1	16.5	24.5	–	21.5	23.2	–	23.1	24.4	–	23.3	–
Ont.	*mm*	–	460	419	622	–	546	589	–	587	620	–	592	–
(Wainio 1962)	Avg *inches*	17.3				22.4			23.7				23.3	
	FL													
Chilliwack R., B.C.	*inches*	19.0	18.7	18.0	–	27.9	27.5	27.6	31.9	31.9	32.2	32.7	38.0	33.5
(Maher and	*mm*	483	475	457	–	709	698	701	810	810	818	830	965	851
Larkin 1955)	Avg *inches*	18.6				27.6			32.0				34.6	

were 12.2–31.5 inches (310–800 mm) in length, and the females 8.2–35.4 inches (210–900 mm). Individual spawners represented 14 different combinations of the factors mentioned above (*see* age–length table).

Sexual maturity is first achieved as early as 1 year by males (rarely) to as late as 6 years by females. In general, the usual age would be 3–5 in all types, with males often maturing a year younger than females. Size at maturity is extremely variable, from 6–10 inches (152–254 mm) in some small lakes or streams, to 16 inches (406 mm) in steelhead and Great Lakes rainbows. A spawning run from Georgian Bay consisted of fish from 16–27 inches (406–686 mm) length, and 3–6 years of age. Individual rainbow trout have been known to spawn in as many as five successive years. If food and other factors are suitable, most mature individuals spawn each year. However, survival is often low and the number spawning more than once can be less than 10%. Generally there is a high degree of homing by spawning adults. It was as high as 94% at Loon Lake, B.C., where fish that mixed in the lake separated to spawn in the inlet or the outlet stream. There is much more wandering in Great Lakes introduced populations.

Maximum size also varies with area, type, and habitat. Steelhead grow to 48 inches (122 cm) and 36 pounds, but 8–9 pounds is the average in the angler's catch. Great Lakes rainbow trout grow to about 36 inches (915 mm) but weight rarely exceeds 20 pounds. The Kamloops type usually do not exceed 6–8 pounds but one taken many years ago in Jewel Lake, B.C., weighed 52 pounds. Rainbow trout grow at least as large as 7½ pounds in Newfoundland, and 17 pounds in Alberta. The present angler record (all types combined) is apparently one caught in Lake Pend Oreille, Idaho, in 1947, which was 40½ inches (103 cm) long, 28 inches (711 mm) in girth, and 37 pounds in weight. Rainbow trout 10–18 pounds win annual anglers contests in Ontario.

Life expectancy can be as low as 3 or 4 years in many stream and lake populations, but that of steelhead and Great Lakes populations would appear to be 6–8 years.

The habitat of stream-dwelling rainbows is usually small to moderately large, but shallow rivers with moderate flow and gravel bottoms, of the pool-riffle type. When in fresh water, steelhead are usually caught in the lower reaches of larger, swift, bouldery rivers of which their spawning stream is a higher tributary. The lake-resident Kamloops type are usually found in moderately deep to deep, cool lakes with adequate shallows and vegetation for good food production. For a lake population to be self-sustaining there must be a gravelly river to which the adults can migrate to spawn. Black (1953) determined the upper lethal temperature of Kamloops trout fingerlings to be 75.2° F (24° C) when they had been acclimated at 51.8° F (11° C). Final preferred temperature calculated by Garside and Tait (1958) was 55.4° F (13° C). Rainbow trout are most successful in habitats with temperatures of 70° F (21° C) or slightly lower, but, so long as there is cooler, well-oxygenated water into which they can retreat they can thrive in lakes which warm at the surface to well over 70° F (21° C) for long periods in the summer. In colder alpine lakes growth rate is slower and maximum size is less.

Generally, the territory utilized by lake-resident rainbow trout is not great. The introduction of the anadromous steelhead into the Great Lakes has resulted in some prodigious journeys. One fish, taken in the Bay of Quinte, Lake Ontario, in January, 1958, had been part of a tagged group released in Great Lakes rivers in Michigan. From release to capture, a period of 8 months, it had travelled about 600 miles, survived a descent of Niagara Falls (unless it negotiated the Welland Ship Canal), and grew 10 inches (254 mm) in length.

In general, rainbow trout feed on various invertebrates including plankton, larger crustaceans, insects, snails, and leeches. Depending on size and location, other fishes (rarely other rainbow trout) and fish eggs (usually salmon) can be important. The bottom organisms it consumes consist mainly of larger crustaceans such as *Gammarus*, and the larvae of virtually all aquatic insects that occur in its habitats. There is usually a shift with increase in size from plankton to insects and crustaceans and then to fishes, if they are available. These trout feed on the bottom most often, but the habit of rising to feed at the surface on emerging or egg-laying insects is well known to most fly fishermen. There have been many detailed analyses of food by size and season of the Kamloops type trout (*see* Neave and Bajkov 1929; Larkin et al. 1950; Crossman and Larkin 1959). The availability of other fishes as food is often considered necessary for the attainment of large size by rainbow trout. Where such fishes are present in large western lakes and in the Great Lakes, rainbows do grow to great size. However, in smaller lakes, rainbow fare well on invertebrates alone. Kamloops type trout introduced into some barren lakes which contained vast numbers of *Gammarus* or other large crustaceans grew to 14 pounds in as few as 3 years. Often this growth rate decreased drastically as trout population increased and food decreased. Other lakes are able to maintain populations of fish to 4 or 5 pounds on invertebrates alone.

Rainbow trout are subject to predation in western streams by other trouts, chars, and coho salmon smolts — in the Great Lakes most of the larger, native predatory fishes are not found in the streams used by young rainbows. Diving birds and a variety of mammals also take a small number. Young rainbow trout potentially compete with all other salmonids for food. Where they are lake resident in the east they compete also with a vast complex of other bottom-feeding fishes. The large adults compete for food with other bottom-feeders and with other predaceous fishes.

An interesting and long-documented history of a single population of angler-exploited Kamloops type rainbow trout is that of Paul Lake, B.C. It exemplifies the typical pattern of invertebrate food and adequate growth before introduction of the redside shiner — a food competitor, the decrease in trout growth through competition, and the changing competitor–predator–prey interaction of the two fishes with time (*see* Larkin et al. 1950; Larkin and Smith 1954; Crossman 1959a, b; Crossman and Larkin 1959; Johannes and Larkin 1961).

Over its range in Canada, the rainbow trout is subject to a wide variety of parasites too extensive to list. Bangham and Adams (1954) gave details of 51 populations of the Kamloops type in British Columbia. Bangham (1955) identified parasites of rainbow trout in Lake Huron, and Sandeman and Pippy (1967) listed parasites of this species in Newfoundland. Hoffman (1967) summarized much of the North American information as follows: fungi (1), protozoans (19), trematodes (20), cestodes (12), nematodes (20), acanthocephalans (9), leeches (2), molluscs (4), gordiaceans (1), crustaceans (6).

The Pacific lamprey parasitizes the steelhead in the Pacific Ocean to a minor extent and the sea lamprey causes multiple, serious wounds which probably bring about direct and indirect mortality of larger rainbows in the Great Lakes.

Relation to man It may simply be said that this species is one of the top five sport fishes in North America and the most important, west of the Rocky Mountains. It is the fly fisherman's delight as it takes a fly without indecision, fights hard at the surface, and leaps often. It is also taken by trolling flies, by trolling or casting other small artificial lures, by still fishing with artificial lures activated by stream current, or with natural baits such as clusters of salmon eggs. The rainbow in all its forms is important not only from the enjoyment it gives anglers across Canada but from the incomes generated by the businesses and industries this pursuit supports. The difficulties of landing a hooked steelhead in a swift, rocky river in winter are legendary and the subject of many books. The more comfortable lake or stream fishing in summer is different but no less enjoyable. The rainbow has been one of the more successful, more appreciated, and less potentially dangerous of the many attempts to introduce a fish to areas beyond its natural range. The flesh is usually bright red and rich in smaller individuals in lakes where the food is invertebrates, or pink to white in larger lakes where they feed on fishes. It is highly acceptable cooked in any way, or when hot-smoked after a brine and sugar cure.

A few thousand cases of canned steelhead are processed annually from those taken by commercial fishermen of Pacific salmons. Small rainbow trout presently for sale in Canada as frozen whole fish are pond-reared in Europe and Japan. Under intensive investigation at present is the possibility of utilizing small prairie potholes for annual commercial crops of rainbow trout. Fish cannot survive over winter in these ponds but invertebrates highly suitable as natural food can, and are very abundant in the summer. Ponds tested to date in Manitoba (21–68 surface acres, 10–25 feet or 3.0–7.6 m deep) have been stocked with 2½-inch (64-mm) trout in April and have produced by October or November trout 10–14 inches (254–356 mm) long, with a yield of 10–105 pounds per acre (Johnson et al. 1970).

Nomenclature

Salmo Gairdnerii (Richardson)	— Richardson 1836: 221 (type locality Columbia River at Fort Vancouver, Vancouver, Wash.)
Salmo iridea Gibbons	— Gibbons 1855: 36
Salmo irideus	— Bean 1894a: 36
Fario gairdneri	— Girard 1859: 313
Salmo masoni	— Suckley 1860: 345
Salmo truncatus	— Suckley 1862a: 3
Salmo purpuratus	— Günther 1866: 116
Salmo stellatus	— Günther 1866: 117
Salmo gairdneri	— Suckley 1874: 114
Oncorhynchus Kamloops	— Jordan 1892: 405 (type locality Kamloops Lake, B.C.)
Salmo Kamloops Jordan	— Jordan and Evermann 1896–1900: 47
Salmo rivularis Ayres	— Halkett 1913: 52
Salmo rivularis kamloops Jordan	— Halkett 1913: 52
Salmo irideus argentatus	— Bajkov 1927: 377
Salmo kamloops whitehousei	— Dymond 1931b: 393

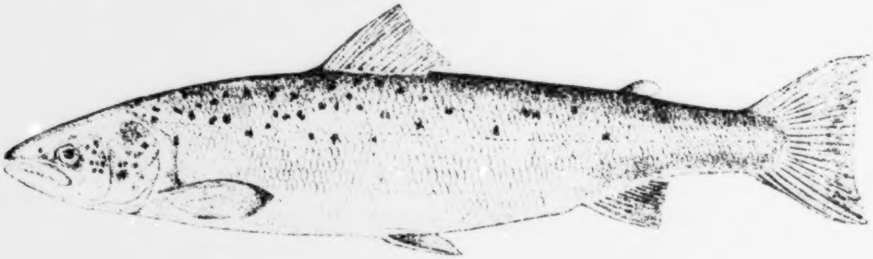
No attempt has been made to list the changing combinations of the names *irideus, gairdneri* and *kamloops* as species or subspecies for the various forms of this trout, nor the changing attitude towards *i* or *ii* endings.

Etymology *Salmo* — Latin name for the salmon of the Atlantic; *gairdneri* — after Dr Meredith Gairdner, a naturalist in the employ of the Hudson's Bay Company.

Common names Rainbow trout, Kamloops trout, steelhead trout, steelhead, coast rainbow trout, silver trout. French common name: *truite arc-en-ciel.*

ATLANTIC SALMON

Salmo salar Linnaeus

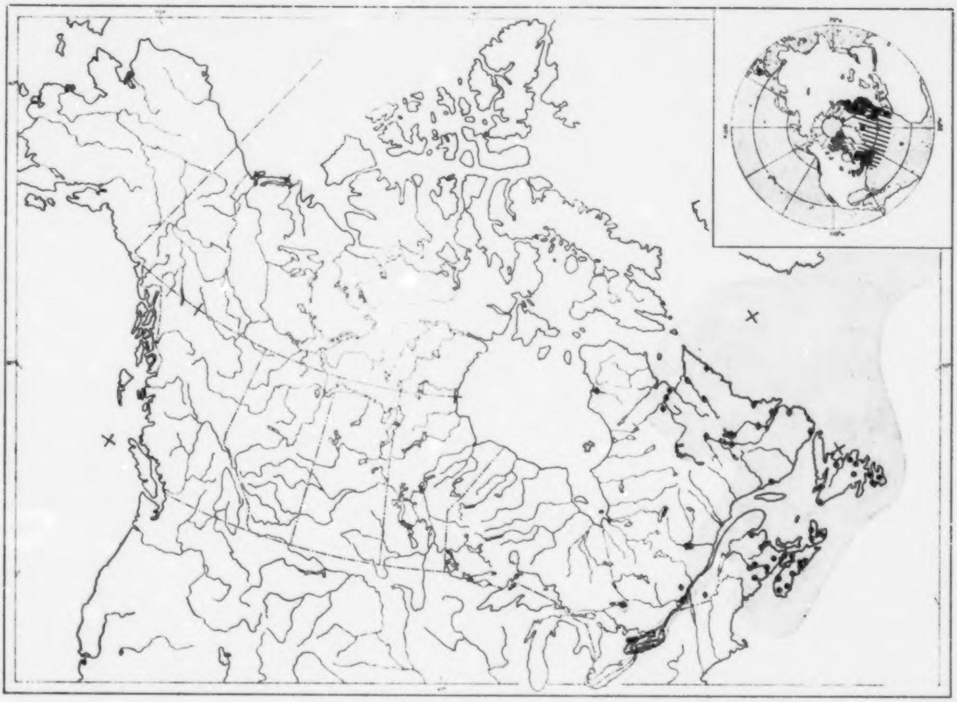


Description Body typically troutlike, elongate, average length about 18 inches (457 mm), somewhat compressed laterally, greatest body depth usually at dorsal fin origin or slightly posterior to it, 18–22% of total length. Head length about equal to or slightly greater than body depth, 20–23% of total length, but most variable during modifications to head during spawning; eye moderate, 14–19% of head length (variable depending on growth rate); snout rounded, its length greater than eye diameter on fish over 12 inches (305 mm) long; mouth terminal, large, maxillary extending posteriorly to posterior margin of pupil when 6 inches (152 mm) long, and seldom to posterior margin of eye except on mature males, which develop a pronounced hook or kype on lower jaw (for information on prespawning transformation of skull, *see* Tchernavin 1943); teeth developed on upper and lower jaws (premaxillary, maxillary, dentary), usually a few teeth in single row on shaft of vomer (none on head), on palatines, on tongue in 2 rows, no hyoid teeth. Gill rakers, total count 15–20. Branchiostegal rays usually 11 or 12 (rarely 10 or 13); in Ungava 11(4), 12(15), 13(2) (Power 1969). Fins: dorsal adipose present; principal dorsal rays 10–12; caudal with shallow fork; principal anal rays 8–11; pelvic rays 9 or 10, a distinct pelvic axillary process present; pectoral rays 14 or 15. Scales cycloid, 109–121 in lateral line, 10–13 scales from posterior edge of adipose base to lateral line; lateral line decurved anteriorly, then straight. Pyloric caeca 40–74 (Belding 1939). Vertebrae 58(1), 59(6), 60(11), 61(3) (Power 1969).

(*See also* Belding 1939; Wilder 1947; Power 1969.)

Colour In the sea, salmon are silvery on sides and silvery white below, the back may be brown, green, or blue. On entering fresh water the adults lose the silvery appearance and become darker; as they approach spawning they take on a bronze and dark brown colouration, sometimes with reddish spots on head and body. The pectoral and caudal fins may become dark. When spawned-out, both male and female become dark in colour and may be called black salmon. The slender young have 8–11 narrow pigmented parr marks on each side with a single red spot between each parr mark along the lateral line. When they become smolts and go to sea, the parr marks are lost and the fish become silvery.

Systematic notes For many years freshwater populations were thought to be taxonomically distinct from normal anadromous populations. Some, such as the salmon of Sebago Lake, Maine, were considered to be distinct species, *Salmo sebago* (Girard 1854; Kendall 1935). Most taxonomists of the time were prone to regard these various



populations as only subspecifically distinct, thus:

Salmo salar salar	– sea-run salmon
Salmo salar sebago	– Sebago Lake salmon
Salmo salar ouananiche	– Lake St. John salmon

In a systematic study of a number of populations, Wilder (1947) was unable to demonstrate consistent differences between the different populations and concluded that subspecific designations were unwarranted. This view has been accepted by most subsequent workers.

Distribution The Atlantic salmon is native to the basin of the North Atlantic Ocean, from the Arctic Circle to Portugal in the eastern Atlantic, from Iceland and southern Greenland, and from the Ungava region of northern Quebec south to the Connecticut River.

In Canada, the Atlantic salmon is found throughout Newfoundland and Labrador, the Maritime Provinces and eastern Quebec and the Ungava region of northern Quebec. A number of populations of landlocked salmon occur throughout the region, especially in Newfoundland, Labrador, and Quebec. A specimen was reported from the mouth of the Kogaluk River on the east shore of northern Hudson Bay (Le Jeune and Legendre 1968) the westernmost limit of the northern range. The salmon formerly occurred in Lake Ontario but was extirpated from that basin before 1900. Innumerable attempts have been made to introduce Atlantic salmon into a number of North American lakes but few have been successful (*see* McCrimmon 1948, 1956; MacKay 1963). In Trout Lake, near North Bay, Ont., a self sustaining population now exists following introductions which commenced in 1935.

Biology The biology of the Atlantic salmon, at least the salient features, has been known to man for centuries, and a wealth of literature has accumulated on many aspects of its life story.

The Atlantic salmon is the classic anadromous fish, that is, it spawns in freshwater streams, the adults return to sea, the young remain in fresh water for 2 or 3 years, then descend to the sea to spend one or more years feeding and growing before returning to fresh water to spawn.

In Canada, Atlantic salmon spawn in October and November. The actual date depends on the region. In the Ungava area of Quebec, Power (1969) observed that spawning was unlikely before the end of September, but farther south it may take place as late as November. Marine salmon move into estuaries and, thence, to fresh water in spring, summer, or early autumn, the approximate time being characteristic for each river. The ability of salmon to surmount falls and other obstacles in the river in order to reach the spawning grounds has been a source of wonder for centuries. Landlocked or permanently freshwater salmon simply move from the lake into the tributary stream to be used for spawning.

As the adults prepare for spawning, the head of the male undergoes transformation. The head elongates and the lower jaw becomes enlarged and hooked at the tip, forming a kype. The actual nesting site is chosen by the female, usually a gravel-bottom riffle area above or below a pool. While the male drives off males and other intruders, the female, while on her side, uses her caudal fin like a paddle and excavates a nesting depression (the redd). During the spawning, several such depressions may be excavated. When it is prepared to her satisfaction, she settles into the nest, the male aligns himself beside her, and the eggs and sperm are released, after which the female covers them with gravel. This operation is repeated many times until spawning is completed. The eggs are large, about 5–7 mm in diameter after extrusion, and somewhat adhesive for a short time. The number of eggs deposited varies from population to population and does not necessarily vary directly with the size of the female. On the average, a female deposits about 700 eggs/pound of body weight. After spawning, the parent fish, now called a kelt, may drop downriver to a pool and rest for a few weeks, or the female may leave and the male remain in the pool. In some cases the males may overwinter in the river. Atlantic salmon often do not die after spawning and may spawn more than once.

The eggs incubate in the gravel during the winter, the rate of development depending upon temperature. Hatching usually occurs in about 110 days at 39° F (3.9° C), usually in April, but the young remain buried in the gravel, absorbing the yolk sac and finally emerging from the gravel in May or June. The young remain in the rapid water until about 2.5 inches (65 mm) long. Growth of parr in the streams is usually rather slow. In the Maritime Provinces parr go to sea, as smolts, when 5–6 inches (127–152 mm) long and 2 or 3 years old. In the Ungava region, however, they do not go to sea until at least 7.1 inches (180 mm) long and at ages of 4–8 years (Power 1969).

Growth in the sea (or lake) is relatively rapid, and some salmon, often males, may return from sea in a year, as grilse, weighing 3–6 pounds. Others may remain at sea for 2 years and return weighing 6–15 pounds. In eastern Canada, few salmon live beyond 9 years, but in Ungava ages to 11 years have been reported by Power (1969). *See* the following table for growth rates of some Canadian freshwater populations.

The size attained by Atlantic salmon varies greatly depending on whether the populations are anadromous (sea-run) or entirely freshwater. Anadromous salmon may weigh as much as 79 pounds 2 ounces (35.8 kg) (Norway) although Yarrell (1836) mentioned the largest fish known to him was a female weighing 83 pounds. A 55-pound (24.9-kg) fish, caught in Grand Cascapedia River, Que., may be a Canadian record. Sea-run salmon range about 5–20 pounds (2.3–9.1 kg); commercially caught fish average about 10 pounds (4.5 kg). "Landlocked" or freshwater salmon, also called "ouananiche," usually average smaller than sea-run, but one

		Age								
		1	2	3	4	5	6	7	8	9
Terra Nova R. System, Nfld.	FL									
(Andrews 1966)	*inches*	3.9	4.4	6.9	8.5	9.9	11.1	12.6	15.2	–
(freshwater)	*mm*	99	113	176	217	250	281	320	385	–
Gambo Pond, Nfld. (Leggett and Power 1969)	*inches*	3.1	6.2	8.1	12.6	14.4	13.7	16.6	17.2	20.9
	mm	80	157	205	322	367	349	421	437	532
Astray L., Ungava (Power 1958)	*inches*	2.5	4.5	6.9	9.8	12.9	16.2	20.0	–	–
	mm	63	114	174	248	328	412	508	–	–
Trout L., Ont.	TL									
(MacKay 1963)	*inches*	–	–	21.2	23.0	29.3	–	–	–	–
	mm	–	–	538	584	744	–	–	–	–
	Wt (*oz*)	–	–	–	55	184	–	–	–	–

weighing 35.5 pounds (16.1 kg) was caught in Sebago Lake, Maine, many years ago (Kendall 1935), and salmon weighing up to 44.7 pounds (20.4 kg) were reported for Lake Ontario (Fox 1930). The average weight of landlocked salmon is probably about 2–4 pounds (907–1814 g), but Lake St. John (Quebec) fish reached a maximum weight of about 7 pounds.

Like most migratory fishes, salmon have a different habitat at each stage of their life history. Thus, the young remain in gravelly streams for 2 or 3 years, then descend the river as smolts, and enter the sea-dwelling phase. When at sea, they may remain within the influence of the estuary or move as far as Greenland, a journey of at least 1500 miles. The life at sea is not well known. Salmon living throughout their lives in freshwater lakes usually spawn in tributary streams, then return to the lake. They remain in shallow upper layers of the lake following breakup, gradually retreating to the cooler deep water as summer advances. With falling temperatures in the autumn, salmon again move into shallower water, ascend the streams to spawn, and repeat the cycle.

When at sea, Atlantic salmon eat a variety of marine organisms including crustaceans such as euphausiids, amphipods, and decapods, and such fishes as sand lance, smelt, alewives, herring, capelin, small mackerel, and small cod. On entering fresh water preparatory to spawning, salmon do not feed, despite their apparent willingness to take an angler's fly. Young salmon in streams feed mainly upon aquatic insect larvae but terrestrial insects may be particularly important, especially in late summer or early autumn. The most important aquatic insect groups used as food are larvae and nymphs of chironomids, mayflies, caddisflies, blackflies, and stoneflies.

Atlantic salmon are preyed upon by many other animals, particularly when they are young. American mergansers and kingfishers have been known to eat large numbers of salmon in Nova Scotia and New Brunswick streams (White 1957). Eels may also eat large numbers of young salmon, *see* White (1933) who noted the remains of 429 salmon fry from the stomach of one 20-inch eel. McCrimmon (1954) observed that northern pike and brook trout fed upon introduced salmon in Duffin's Creek, Lake Ontario.

At sea, salmon have been found in the stomachs of sharks, pollock, tuna, and swordfish. When caught in traps, salmon are often eaten by marauding seals but it is not known if seals feed on free-swimming salmon.

The number of species of parasites known to infect Atlantic salmon is numerous and includes nematodes, cestodes, trematodes, acanthocephalans, parasitic copepods (some of which are called "gill maggots"), and the fish louse, *Argulus*. Recent reviews of the parasites infecting salmon in two eastern Canadian localities have been provided by Sandeman and Pippy (1967) and Threlfall and Hanek (1970) (Newfoundland), and

Power (1969) (Ungava). A most comprehesive account of parasites known to infect landlocked salmon in Maine was provided by Havey and Warner (1970). For additional information on parasites *see also* Jones (1959). Hoffman (1967) listed parasites in *S. salar* in fresh waters of North America and northern Europe.

Perhaps the most serious disease of salmon is the so-called salmon disease or Ulcerative Dermal Necrosis or simply UDN, which attacks European fish. Salmon disease, believed to be caused by a virus, is highly infectious. It manifests itself as serious skin lesions, resembling ulcers, which enlarge and coalesce. The breaks in the skin permit the entry of secondary infections. The disease is usually fatal.

Relation to man Few animals, whether fish, bird, or beast, have attracted as much attention through the ages as has the Atlantic salmon. Prized by the Gauls, then by the Romans, an abundant commercial fish in the British Isles, mentioned in the Magna Charta, revered by the sportsman and esteemed by gourmets, its relation with man has been truly unique. After centuries of exploitation, Yarrell (1836) told us that the last salmon was caught in the Thames in 1833. After less than a century of exploitation the last salmon was removed from Lake Ontario about 1890. (For information on Lake Ontario salmon *see* Richardson 1908; Fox 1930; Huntsman 1944; McCrimmon 1954.)

The Atlantic salmon was one of the first Canadian fishes in the Great Lakes region to disappear as a result of man's careless use of natural resources. It was to be the first of many. In Lake Ontario the erection of mill dams on streams denied it access to spawning grounds. It was also the first to suffer from DDT sprays (in New Brunswick), hydroelectric dam construction, domestic pollution, and a thousand and one other indignities thrust upon the environment by man.

One of the most serious threats to continued survival of anadromous stocks is the commercial fishery off Greenland which threatens all populations, for it is to Greenland waters, apparently, that anadromous salmon from both sides of the Atlantic go to feed. The catch of salmon in Greenland waters, which was 127 metric tons in 1961, reached 1588 metric tons in 1967 and dropped to 1200 in 1968. This is both an inshore and a high seas fishery, and although only Greenlanders can fish inshore, any nation can fish the high seas. It is the latter aspect of the fishery that poses the greatest threat.

Atlantic salmon is world renowned, both as a game fish par excellence, and as a commercial species. Canada possesses the finest salmon waters left on earth but the future of the species is uncertain at the rate at which the environment is being despoiled. For a review of the Atlantic salmon on the world scene, *see The Atlantic Salmon, a vanishing species?* by Anthony Netboy (1968). For details of North American fisheries, *see* Huntsman (1931), Dymond (1963) with extensive reference lists, Power (1969), and Havey and Warner (1970).

Nomenclature

Salmo salar	— Linnaeus 1758: 308 (type locality seas of Europe)
Salmo omisco maycus	— Walbaum 1792: 65
Salmo salar (Auctorum)	— Richardson 1836: 145
Salmo Gloverii Girard	— Adams 1873: 306
Salmo sebago	— Girard 1854b: 380
Salmo salar ouananiche McCarthy	— Jordan and Evermann 1896–1900: 487
Salmo ouananiche McCarthy	— Jordan, Evermann, and Clark 1930: 56

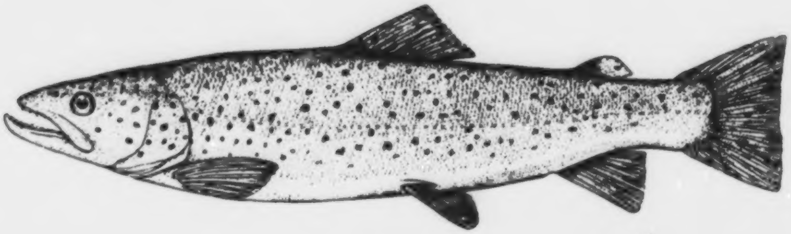
(For detailed synonyms and references *see* Dymond 1963)

Etymology *Salmo* — Latin name for the salmon of the Atlantic; *salar* — old name from "salio," to leap.

Common names Atlantic salmon, lake Atlantic salmon, ouananiche, common Atlantic salmon, Kennebec salmon, landlocked salmon, sebago, sebago salmon, salmon, black salmon, grilse, kelt, grayling (in N.S.), slink (spent fish), grilt, fiddler, smolt (young running to sea), parr (before running), saumon, bratan. French common names: *saumon atlantique, saumon d'eau douce, ouananiche.*

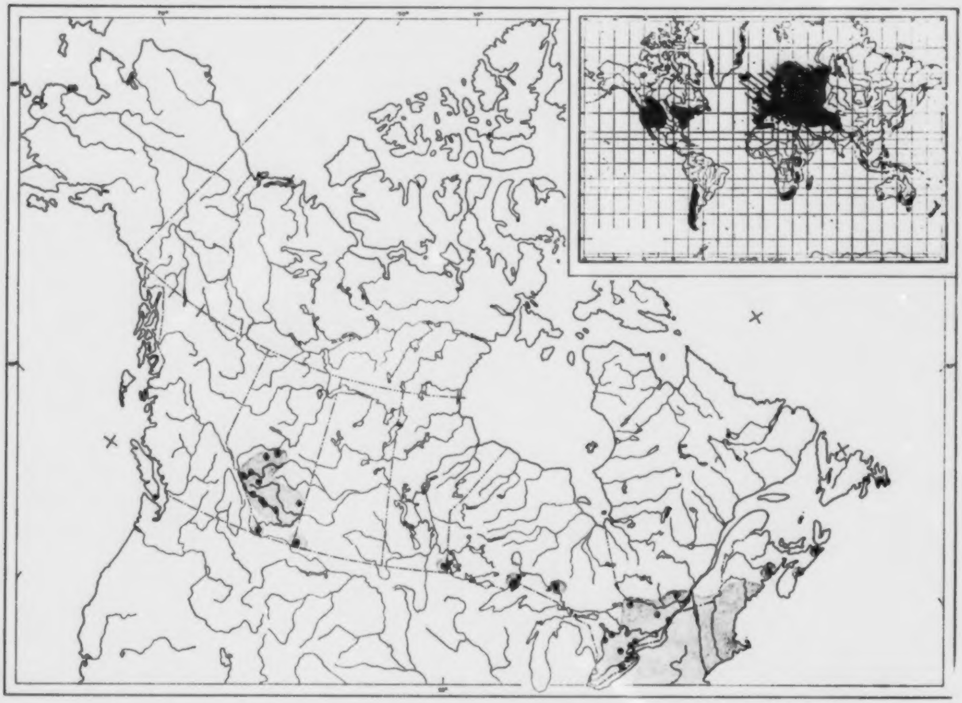
BROWN TROUT

Salmo trutta Linnaeus



Description Body typically troutlike, elongate, average length about 16 inches (406 mm), compressed laterally, greatest body depth at dorsal fin origin, 20–24% of total length. Caudal peduncle deep, its depth 12.5% of total length or greater. Head long, about 23% of total length of adults; eye moderate, 16–18% of head length in adults; snout rounded, its length greater than eye diameter on adults; mouth terminal, large, maxillary extending posteriorly to posterior margin of eye even at lengths of 6 inches, (152 mm) and past posterior margin of eye at large sizes; mature males develop pronounced hook or kype on lower jaw; teeth developed on upper and lower jaws (premaxillary, maxillary, dentary), usually many teeth on head and shaft of vomer, on palatines, on tongue in 2 rows, no hyoid teeth. Gill rakers, total count 14–17. Branchiostegal rays usually 10. Fins: dorsal adipose present; principal dorsal rays about 12–14; caudal square or truncate, a shallow fork in young; principal anal rays about 10–12, fin rounded on males, falcate on females (Gruchy and Vladykov 1968); pelvic rays 9 or 10, a distinct pelvic axillary process present; pectoral rays 13 or 14. Scales cycloid, small, 120–130 in lateral line, 13–16 scales from posterior edge of adipose base to lateral line; lateral line decurved anteriorly, then straight. Pyloric caeca 30–60. Vertebrae 56–61.

Colour In streams, a light brown or tawny overall colouration, brown on the back, becoming silvery on the sides, with pronounced black spots on back, sides of body, and head, the spots tending to spread below the lateral line anteriorly, but less so posteriorly. Spots often surrounded with a lighter ring or halo. Rusty red, irregularly shaped spots also on sides. Dorsal and adipose fins with dark spotting, but caudal never with more than occasional vague spots, these not arranged in a series of radiating lines of spots distinctly visible even to tip of fin (as in rainbow trout). The adipose fin with an orange or orange-red colouration. The fins of adults have a smoky, opaque,



sometimes yellowish colouration, and on large males in autumn the lower fins may become slate coloured.

In large lakes or in the sea, overall colouration silvery, masking most of the spotting on body; spots on head small and numerous; adipose usually with orange or orange-red hue.

Young brown trout with 9–14 short, narrow parr marks and a few reddish spots along the lateral line.

Systematic notes The brown trout is a very clearly defined species, its closest relative being the Atlantic salmon, *Salmo salar*. In its native range it is most variable in rate of growth, shape, colour, and many other features, giving rise to the naming of a number of subspecies. The names applied to the brown trout introduced to North America were often derived from the name of the place of origin of the introduced stock. Thus, we hear of Lochleven trout, *Salmo trutta levenensis* (at one time called *Salmo levenensis*), German brown trout, *Salmo fario* or *S. trutta fario*, and so on. Despite the name applied, all are now recognized as forms of the brown trout, *S. trutta*.

Brown trout can be hybridized with brook trout to produce a strikingly marked stocky fish, sometimes called a "tiger trout," but the mortality of eggs and alevins is high. Brown trout have also been artificially hybridized with rainbow trout and other salmonids. *See* Buss and Wright (1956, 1958) for additional information.

Distribution The brown trout is native to Europe and western Asia, its range includes Iceland, the British Isles, and the Eurasian mainland from Cape Kanin to the Aral Sea and Afghanistan westward throughout Europe.

It was introduced into North American waters as early as 1883 (New York and Michigan) and the following year, 1884, it was introduced into Newfoundland. Introductions into Canadian waters commenced with Quebec in 1890, Ontario in 1913, New Brunswick in 1921, and Nova Scotia in 1923. Eventually all Canadian provinces have had successful introductions except Prince Edward Island, Manitoba, and the Northwest Territories (MacCrimmon and Marshall 1968).

For a review of brown trout introductions into Canada and other parts of the world *see* MacCrimmon and Marshall (1968) and MacCrimmon et al. (1970).

Biology Brown trout spawn in late autumn to early winter. Brook trout have usually completed spawning before brown trout begin, but Greeley (1932) noted both species used the same spawning grounds in Michigan between November 5 and 25. In Ontario, Mansell (1966) reported that spawning activities of the brown trout started about October 15 and continued through early November, during which period water temperatures were between 44°–48° F (6.7°–8.9° C). Spawning may extend into January, at least in British Columbia (Carl 1938).

Spawning requirements are basically the same as those of brook trout, that is, shallow, gravelly headwaters, but Eddy and Surber (1960) noted that, although they entered Lake Superior streams in October and November to spawn, many spawned on rocky reefs along the shore. For many years considerable doubt was expressed that brown trout were successfully reproducing in many Canadian waters (Catt 1950; Dymond 1955). It now seems clear that reproduction was taking place, and successfully, but was unobserved (Catt 1950; Carl 1938).

The female creates a shallow depression (redd) in the gravel, in which the spawning fish deposit the eggs and sperm. The process is repeated many times, but when spawning is completed, the female covers the redd with gravel.

The number of eggs deposited depends upon the size of the female for, as usual, larger fish deposit more eggs. In the Cowichan River, B.C., females at age 5 and 6 averaged 2020 eggs. The eggs tend to be amber coloured and to have a diameter of about 4–5 mm. In a recent study in Pennsylvania (McFadden et al. 1965), differences in fecundity were demonstrated to be related to differences in stream fertility. The authors also noted a difference in egg diameter between two populations.

More growth studies have been conducted on brown trout in United States waters than in Canadian. However, in a recent Ontario study, Marshall and MacCrimmon (1970) observed ages to 13 years. In southern Ontario brown trout attain a total length of about 6.5 inches (165 mm) at age 1, 9.8 inches (249 mm) at age 2, 15.3 inches (388 mm) at age 3, and 16.8 inches (427 mm) at age 4 (Mansell 1966). For information on growth rates in various parts of the world *see* Carlander (1969).

Brown trout grow to a large size. The often-quoted record for a sea-run fish is 39 pounds 4 ounces, for a 40.5-inch brown trout caught in Loch Awe, Scotland, in 1866. Two large fish were caught in recent years in Witless Bay, Nfld.; one weighed 28 pounds 8 ounces, the other 27 pounds 10 ounces (Williamson 1963). In Ontario, brown trout weighing up to 14 pounds 12 ounces have been caught. Although brown trout over 10 pounds in weight are not rare, the average size in inland streams is of the order of 1 or 2 pounds.

In Canada the brown trout has been introduced mainly into stream or river habitats, although a number of lake or sea-run populations now exist. Its requirements are essentially the same as for the native brook trout, with which it is usually in competition, but the brown trout can remain active and thriving at slightly higher temperatures than brook trout. Optimum temperature range for brown trout is said to be 65°–75° F (18.3°–23.9° C) (Brynildson et al. 1963). There has been a tendency to believe that brown trout do best in the slower-moving waters of the lower reaches of trout streams but such a view is not supported by the work of Marshall and MacCrimmon (1970) on the Sydenham River, Ont.

Brown trout are carnivorous and eat a wide variety of organisms, particularly aquatic and terrestrial insects and their larvae, crustaceans, especially crayfish, molluscs, salamanders, frogs, and rodents and, of course, a wide variety of fishes. Fishes and crayfish figure prominently in the diet of larger brown trout; indeed Idyll (1942) observed that even 4-inch brown trout would eat other trout; but fish is not usually considered to be significant in the diet of brown trout under 12 inches long.

The larger fish tend to feed at dusk and even later (Needham 1938), a point reinforced by Eddy and Surber (1960) who noted "... the large ones are seldom taken except at twilight and sometimes after dark."

Large brown trout may feed upon smaller trout, but such predation is deplored in heavily fished areas. Mergansers are also regarded as predators, especially during fall and winter in certain areas. Attempts in Michigan to reduce predation in a stream system by removing large brown trout and discouraging mergansers was not markedly successful (Shetter and Alexander 1970).

Sandeman and Pippy (1967) noted that the acanthocephalan *Echinorhynchus lateralis* was identified from 76% of the 23 brown trout examined in their island-wide survey of Newfoundland. Other parasites recovered were trematodes *Apophallus brevis* (8.7%), *Crepidostomum farionis* (8.0%), *Discocotyle salmonis* (4.3%); nematode *Metabronema salvelini* (8.0%); cestodes *Eubothrium salvelini* (4.3%), *Dibothriocephalus* sp. (4.3%); and protozoan *Trichophyra piscium* (4.3%).

Threlfall and Hanek (1970) noted all 22 specimens of brown trout examined from waters of the Avalon Peninsula, Nfld., were infected, and reported the first record of *Ergasilus* sp. for this species in Newfoundland.

See Davis (1953) for a discussion of furunculosis, *Bacterium salmonicida*, the bacterial disease affecting salmonid fishes, particularly brown and brook trout. The brown trout was suggested by Mansell (1966) to be a dormant carrier of furunculosis in Ontario waters.

Hoffman (1967) listed the parasites of the brown trout from the fresh waters of North America, Europe, and USSR.

Relation to man For many years the brown trout enjoyed only limited success as a game fish in Canadian waters. Many anglers objected to continued plantings because these trout were thought to be too difficult to catch. Biologists and management officers were concerned because browns were thought to displace native brook trout, either by competition or direct predation. Also browns were found to be carriers of a disease of brook trout, called furunculosis. Ontario maintained a brood stock and hatchery for brown trout culture but closed down this operation about 1960 (Mansell 1966). However, since that time, brown trout have become increasingly popular among both anglers and biologists alike. The larger ones especially, are somewhat more resistant to angling pressure than large brook trout. They can withstand the less favourable environment of the lower reaches of streams and rivers that are unsuitable to brook trout. They grow faster and also live longer than brook trout and, thus, a larger number of year-classes are available in a stream at any one time. Recent work by Marshall and MacCrimmon (1970) suggested that the introduction of brown trout to streams supporting native brook trout but subjected to heavy fishing pressure, should result in the establishment of self-sustaining populations of both species, and improve the overall harvest and quality of the angling. *See also* Shetter and Alexander (1965), Brynildson et al. (1963), Cooper (1952, 1953).

Nomenclature

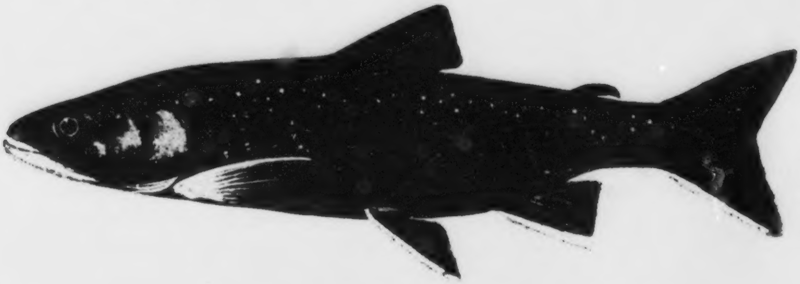
Salmo trutta	— Linnaeus 1758: 308 (type locality Europe)
Salmo fario	— Linnaeus 1758: 309
Salmo eriox	— Jordan 1926: 141
Salmo levenensis	— Günther 1866: 101

Etymology *Salmo* — Latin name for salmon of the Atlantic; *trutta* — Latin name for trout.

Common names Brown trout, German brown trout, German trout, German, English brown trout, von Behr trout, Lochleven trout, European brown trout, truite, breac, gealag, brownie. French common name: *truite brune*.

ARCTIC CHAR

Salvelinus alpinus (Linnaeus)



Description Body typically troutlike, elongate, average length to about 15–18 inches (381–457 mm) but variable, somewhat rounded, greatest body depth below dorsal fin origin but body depth variable dependent upon size, sex, and state of maturity, about 20% of total length. Head short, 22–25% of total length; eye large, its diameter equal to or less than snout length, but relative size most variable, approximately 16–30% of head length; snout somewhat rounded, its length greater than eye diameter on large fish (over 400 mm); mouth terminal, large, maxillary extending posteriorly to beyond posterior margin of eye of migratory char, but may not in freshwater char; mature males may develop a hook or kype on lower jaw (but Backus (1957) says rarely in Labrador); teeth developed on upper and lower jaws (premaxillary, maxillary, and dentary) on head of vomer only (not on shaft), on palatines, on tongue 10–24 in 2 rows, teeth on basibranchial bones variable, 20–85. Gill rakers on upper limb of arch 7–13, on lower limb 12–19. Branchiostegal rays total range 10–13 (10–12 + 10–13). Fins: dorsal adipose present; principal dorsal rays 10–12 (all rays 12–16); caudal distinctly forked; principal anal rays 8–11 (all rays 11–15); pelvic rays 9–11, a distinct pelvic axillary process present; pectoral rays 14–16. Scales cycloid, small, pores along lateral line 123–152, lateral line slightly decurved anteriorly then straight. Pyloric caeca, total range 20–74 (average in lower Yukon area about 29, elsewhere in North America about 44). Vertebrae 60–71.

(*See also* Vladykov 1954, 1957; McPhail 1961; Scott and Crossman 1964; McPhail and Lindsey 1970.)

Colour Arctic char may be exceedingly colourful, as when spawning, or may exhibit the relatively drab silvery colour of nonspawning, landlocked adults, or one of a myriad of colour combinations between these extremes. The startlingly brilliant colour assumed by spawning or near-spawning adults defies adequate verbal description. The colour plate facing page 218, depicts the colour of an anadromous male upon entering fresh water. Under these conditions the back is often dark green or blue-green, the sides silvery blue with scattered orange or red spots, and the belly whitish, or a brilliant orange-red may suffuse the sides and extend across the belly. Sea-run fish, or those caught in estuaries, may be steel-blue on the back, silvery blue on sides with numerous large red, pink or cream coloured spots on sides — Hudson Bay fish often display this colouration. The arctic char in Quebec lakes, sometimes called "Quebec Red trout," may also show this kind of colouration but the phase of orange-red flanks and underparts is most spectacular and better known. Some freshwater populations appear to remain highly coloured at all times (Upsalquitch Lake, N.B., and Kenai Peninsula, Alaska) whereas others, such as some on insular Newfoundland, are silvery with dark green backs and dusky fins. Fins of arctic char may be clear or transparent on small, young fish but are opaque and often dusky on adults; dorsal and caudal usually dusky, anal, pectorals, and pelvics light, but all lower fins usually of brilliant hue during spawning. The leading edges of pectorals, pelvics, anal, and, sometimes, caudal fins have a narrow margin of immaculate white.

Small char have 10–15 irregularly arranged oval parr marks on the sides.

The flesh of anadromous and most freshwater char is usually orange-red in colour but may be pink or even white. Flesh colour of Labrador specimens was discussed by Andrews and Lear (1956).

For additional colour descriptions *see* Backus (1957), Scott and Crossman (1964), and McPhail and Lindsey (1970).

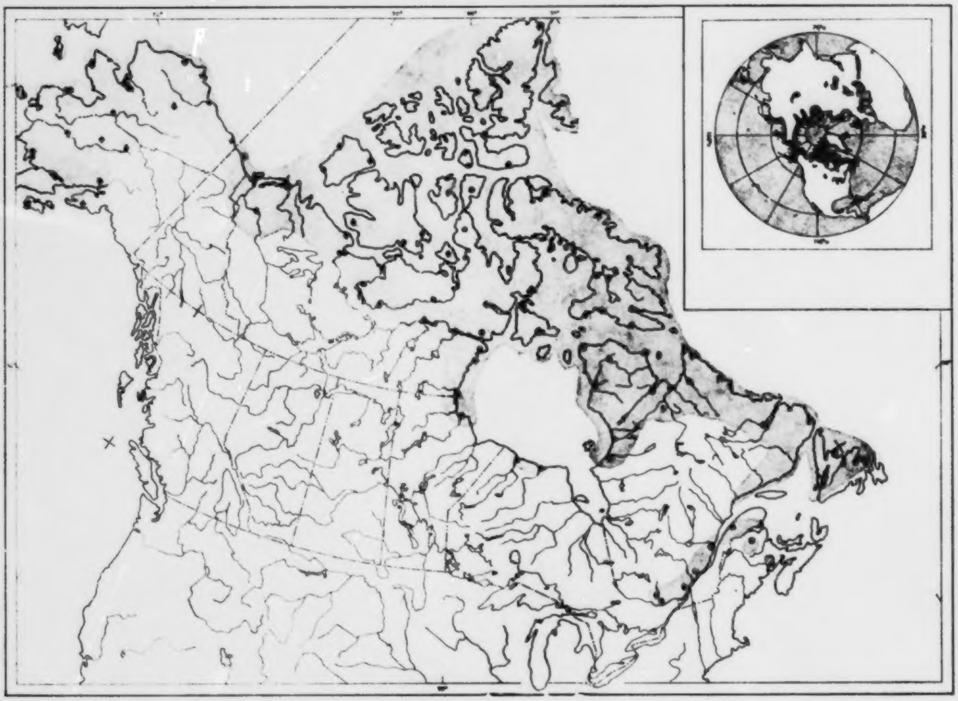
Systematic notes The species was named by Linnaeus (1758), based on specimens from Lapland. The first North American descriptions were of four species described by Sir John Richardson (1835) as *Salmo Rossii*, *S. Hearnii*, *S. alipes*, and *S. nitidus*. Most ichthyologists restrict the genus *Salmo* to the Atlantic salmon and its relatives, and place the chars in the genus *Salvelinus*, but some Europeans still use the genus *Salmo* for the arctic char. During the 1800's more species of North American char were described as exploration of new lands continued. Some relict freshwater populations, such as *Salvelinus marstoni* and *S. oquassa*, are still regarded as valid by a few ichthyologists although most place them in the synonymy of *S. alpinus*. A thorough review of the early nomenclature was given by Martin (1939).

The state of the systematics of the arctic char was clarified greatly by McPhail's (1961) review, in which he demonstrated the specific distinctness of *Salvelinus alpinus* and *Salvelinus malma*. His work also indicated that within *S. alpinus* were at least two recognizable groups that differed from each other in the *mean* number of gill rakers and of pyloric caeca. Central and eastern Canadian char have mean numbers as follows: gill rakers 15–17, pyloric caeca 36–53; northwestern Canadian and northern Alaska char, gill rakers 13 or 14, pyloric caeca 27–31. Char in southwestern Alaska resemble those in eastern Canada. McPhail recommended that subspecific designations for *Salvelinus alpinus* be avoided until the relationship of North American and Eurasian char has been determined.

Electrophoretic patterns of five protein groups from seven geographically isolated populations of arctic char from Canada and the United States were compared by Saunders and McKenzie (1971). These authors concluded that the populations sometimes named *S. marstoni*, *S. aureolus*, and *S. oquassa* were not specifically distinct from *S. alpinus*.

For additional information *see* McPhail (1961), McPhail and Lindsey (1970), and Saunders and McKenzie (1971).

Distribution The arctic char has the most northerly distribution of any freshwater fish. It has a circumpolar distribution and is



found in inshore marine waters, lakes, and rivers around the northern hemisphere, including northern North America, northern Asia, northern Europe (especially the Scandinavian countries), Iceland, Greenland, and innumerable arctic islands. It may be anadromous, or confined entirely to fresh water (landlocked). Freshwater populations occur in more southerly latitudes than anadromous forms and are found in Europe, including parts of the Alps, in the British Isles, and in North America in eastern Canada, Maine, and New Hampshire.

In Canada, arctic char occur in insular Newfoundland, Labrador, and extreme eastern Quebec, coastwise, and north along the Atlantic coast to Hudson Strait, Hudson Bay, and the arctic archipelago, west through the territories to Alaska, including the Aleutian Islands.

Throughout its northern coastal distribution, arctic char does not usually range far inland except in the larger rivers. Isolated freshwater populations occur in eastern Canada in insular Newfoundland, New Brunswick (3 lakes at least), and southeastern Quebec (many lakes).

Biology In arctic waters, char spawn in autumn, usually in September or October, over gravel or rocky shoals in lakes, or in quiet pools in rivers, at depths of 3–15 feet (1.0–4.5 m). Farther south, char may spawn as late as November or December, as in the Matamek River, Que. (Saunders and Power 1969). Although the males establish and guard territories, the nest or redd is prepared by the female who uses her caudal fin, paddle-like, to clear debris from the site. Actual spawning takes place during the day, at temperatures around 39° F (4° C). A spawning female is usually attended by one male during deposition and fertilization of the eggs. (*See* Fabricius and Gustafson 1954, for a discussion of spawning behaviour of Scandinavian char under laboratory conditions.) Males usually mate with more than one female. Anadromous females usually contain 3000–5000 eggs. Frobisher Bay females, having an average length of 22 inches (560 mm), averaged 3589 eggs, while females from George River, Ungava, 16.2 inches (412 mm) average length, contained an average of 2726 eggs. The eggs are large and when deposited are 4–5 mm in diameter. In some populations, the females mature at lengths of about 6–7 inches (152–178 mm) or less and, since the eggs are large, very few are produced (Backus 1957). Females spawn every second or third year, but seldom every year except in southern parts of the range. The eggs develop, buried in the gravel, over the winter, exposed to temperatures of about 32°–36° F (0.0°–2.2° C). The eggs are killed by temperatures above 46° F (7.8° C). Hatching is thought to occur around April 1, but emergence from the gravel probably does not take place until breakup of the ice about mid-July. At this time, fry are about 1 inch (25 mm) long.

Young anadromous char move out of the rivers and downstream to the sea when 6–8 inches (152–203 mm) long. Frobisher Bay char probably make their first downstream migration during the summer at ages 5–7, according to Grainger (1953).

Growth rates vary greatly among different populations but, in general, growth is slow. Ages are more accurately determined by using otoliths than scales, for although scales may be useful during the first 3 or 4 years of life, they do not usually form until about age 2. The use of otoliths was described, with illustrations, by Grainger who used the largest otolith, the sagitta, for aging Frobisher Bay char. However, the wide variations that exist across the Canadian arctic make generalizations misleading, for char in Labrador reach commercial size in 5 years, in the most northerly part of their range in 9 years, and in the central Canadian arctic in 16 years.

Growth rates for a number of Canadian localities are given in the table, p. 205.

Hunter (1966) observed that, on average, full size was attained at about 20 years of age, and although some may have lived as long as 40 years they did not become much larger than 20-year-old fish. The average weight of sea-run char is about 2–10 pounds. In 1960, a 15.8 pound char was caught in the Severn River, Hudson Bay, Ont. McPhail and Lindsey (1970) gave size to 38 inches (960 mm) and weight of 26 pounds (11.8 kg). The largest arctic char known to the present authors was one weighing over 27 pounds (12.2 kg), caught in the Tree River, N.W.T., in 1970 (J. G. Hunter, personal communication). A 20-pound 5-ounce char was reported caught in the Tree River, N.W.T., in 1962. A recognized angling record by ***Field and Stream*** magazine was a 19-pound 15-ounce char, 33.75 inches (856 mm) long, caught in Finger Lake, Que., in 1959.

Arctic char may be either anadromous, moving downstream to the sea in spring, returning in the autumn, or they may remain permanently in fresh water. Downstream migrants usually remain in the vicinity of the estuary, although tagged fish have been captured as far as 80 miles from the river of origin (Hunter 1966). Anadromous arctic char that overwinter in lakes, begin to run to sea before or during breakup, usually completing the run by the end of July and returning in the autumn of the same year. The young fish in the run are the last to move downstream or upstream. Char cannot leap like Atlantic salmon and depend on moving in with the tide to surmount obstacles. For additional information on movements of anadromous char, *see* Grainger (1953) and Andrews and Lear (1956).

Populations of char dwelling permanently in Canadian lakes have received little attention although some populations that exist in eastern Canada attain weights in excess of 2 pounds. Populations of freshwater arctic char in Newfoundland were described by Seabrook (1961) and in Maine by Everhart and Waters (1965). A very thorough study of char in Keyhole Lake, Victoria Island, N.W.T., was made by Hunter (1970).

Arctic char are carnivorous but have an exceedingly varied diet. A study of 450 char stomachs from Frobisher Bay, Baffin Island, revealed 30 different species of vertebrate and

		Age (*years*)																						
	FL	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+	18+	19+	20+	21+	22+	23+	24+	>24+
Baffin Is. (Frobisher Bay) (Grainger 1953)	*Inches*	–	–	3.6	5.1	5.5	6.8	11.9	13.3	14.3	16.3	16.7	19.0	20.1	21.8	21.9	20	23.6	24.1	25.6	25.3	25.9	26.7	26.7	20.1–32.5
	mm	–	–	90	130	139	172	302	337	363	414	425	484	510	553	557	559	600	613	649	642	658	678	678	510–825
NE Labrador (5 locations on NE Coast) (Andrews & Lear 1956)	*Inches*	–	–	–	17.5	17.9	18.4	18.9	18.9	19.5	19.3	20	20.2	20.8	22.5	27.3	–	–	–	–	–	–	–	–	–
	mm	–	–	–	445	454	468	480	480	495	490	507	512	529	571	692	–	–	–	–	–	–	–	–	–
Quebec (Matamek L.) (Landlocked populations) (Saunders & Power 1969)	*Inches*	–	4.7	6.4	6.9	7.4	9.5	10.9	12.2	14.4	15.6	16	16.7	16.4	16	–	–	–	–	–	–	–	–	–	–
	mm	–	120	163	176	187	240	276	309	366	395	406	423	417	405	–	–	–	–	–	–	–	–	–	–
N.W.T. (W coast of Hudson Bay) (Sprules 1952)	*Inches*	–	–	12.5	15	16.1	17.5	18.4	19.4	20.6	22.3	23.7	25.1	25	–	26.8	31	29.5	–	–	–	32.3	–	–	–
	mm	–	–	318	381	409	445	467	493	523	566	602	638	635	–	681	787	749	–	–	–	820	–	–	–
	Wt (*oz*)	–	–	12	24	32	36.6	42.9	54.1	60	78.2	100	106.7	118.1	–	132	185.3	192	–	–	–	256	–	–	–
N.W.T. (Little Fish L.) (Landlocked populations) (Sprules 1952)	*Inches*	6.4	6.5	7.4	7.5	9.1	10.3	10.8	11.2	12.3	12.1	13.8	13.6	13.8	14.9	–	–	–	–	–	–	–	–	–	–
	mm	163	165	188	190	231	262	274	284	312	307	351	345	351	378	–	–	–	–	–	–	–	–	–	–
	Wt (*oz*)	1.0	1.5	2	2	4.3	4.5	7	8	9	10	12.7	14.3	15.7	20	–	–	–	–	–	–	–	–	–	–

invertebrate animals that had been eaten (Grainger 1953). Amphipods (of many species) and mysids were among the more important invertebrates consumed while sculpins (especially *Myoxocephalus groenlandicus*), lumpfishes, seasnails (*Liparis* sp.), and arctic char were the fishes eaten. Char stomachs from other arctic localities, examined by Grainger, contained the arctic cod (*Boreogadus saida*), *Triglops pingeli*, and the sand lance (*Ammodytes*). Study of 1318 stomachs from a Victoria Island lake by Hunter (1970) indicated that plankton, insects and algae were most frequently eaten. At Term Point, Hudson Bay, Sprules (1952) reported sand lance to be the most important single food item in 30 fish examined. In Labrador, Andrews and Lear (1956) reported the capelin to be the most important food item. Arctic char seem able to utilize for food any smaller creature that appears in their habitat.

A freshwater population of char was studied in Matamek Lake, Que., by Saunders and Power (1969), who reported that char under 8 inches (200 mm) ate aquatic insect larvae and small clams, whereas char over 8 inches long ate smelt (*Osmerus mordax*), brook trout (*Salvelinus fontinalis*), and sticklebacks. Smelt was the main food of larger fish, making up 60% of the diet.

Arctic char appear to suffer no serious natural predation, except cannibalism. Such predation is usually considered to be minor. Small young char are often eaten by their larger relatives and may also fall prey to terns and loons; larger ones are eaten by seals.

The parasites of arctic char from Canadian waters have received little attention in the literature except in studies in Labrador by Andrews and Lear (1956). These authors observed a light infection by the roundworm, *Philonema* sp. (except at Nain), adults of which occurred in the body cavity, and immature stages (of this or another species) were encysted in liver, gonads, spleen, peritoneum, and the viscera in general. Heavy infections by a tapeworm, *Eubothrium salvinale* were reported for nearly all localities.

Hoffman's (1967) list of parasites referred mainly to arctic char in waters of the USSR.

Relation to man Arctic char was the only fish of real economic importance to polar and central Eskimos (Rostlund 1952) and is still used as food by coastal Eskimos for themselves and their dogs. Most fish were caught in nets or traps in rivers or river mouths during the downstream or upstream runs. Where conditions permitted, such as below Bloody Falls on the Coppermine River, they were speared. Although summer was the most productive time for fishing, char were also fished through the ice either with a handline or using a lure and spear. They were eaten fresh, smoked, salted, or dried.

In recent years, arctic char has become a gourmet food for the restaurant trade in many large North American cities. Frozen char are shipped to southern markets from commercial fisheries operated in the Central Canadian Arctic and Labrador. Upward of 100,000–200,000 pounds are marketed annually. Char are classified as red, pink, or white according to flesh colour, red commanding the highest price. In Labrador, white-fleshed char are not marketed but are hung on poles and dried for local consumption.

Another highly priced delicacy is canned arctic char, now processed along with whitefish and other local products in a small cannery operated by Eskimos on the west coast of Hudson Bay.

A growing interest in the arctic char as a sport fish has become evident in North America as affluent anglers seek more exotic prey. Its magnificent colouration, excellent flavour and texture (better than the best salmon according to "experts"), rather typical char tactics when hooked, and relative inaccessibility, combine to make it a highly desirable quarry. Hopefully, arctic char stocks will be carefully monitored to prevent overexploitation, a real threat to the species in view of its slow rate of growth and its availability due to increased arctic traffic, not to mention the North American's unenviable record for the destruction of wildlife.

The greatest danger to the arctic char is the white man, not the Eskimo or Indian who, for centuries, have used but not destroyed the stocks. Rather, it is the uncontrolled commercial fishery, rapacious sportsmen, and the results of short-sighted progress in the form of oil well drilling and spillage, and other side effects of our twentieth century style of progress. The overexploitation of the Frobisher Bay fishery in just 10 years of fishing should serve as a shameful lesson.

Nomenclature

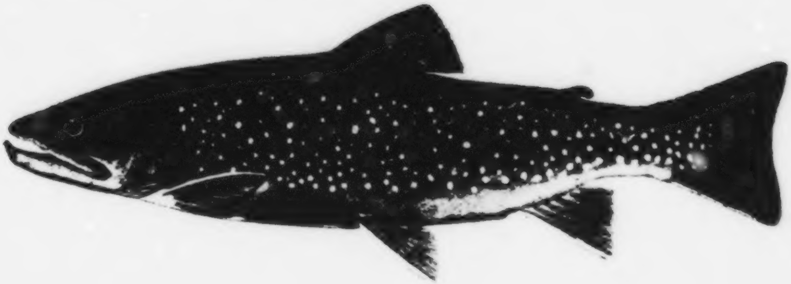
Salmo alpinus — Linnaeus 1758: 309 (type locality Lapland, W. Gothland, etc.)
Salmo stagnalis — Fabricius 1780: 175
Salmo rivalis — Fabricius 1780: 176
Salmo Hearnii — Richardson 1823: 806
Salmo Rossii — Richardson 1835: LVI
Salmo alipes — Richardson 1835: LVII
Salmo nitidus — Richardson 1835: LVII
Salmo oquassa — Girard 1854a: 262
Salmo arcturus — Günther 1877a: 294
Salmo Naresi — Günther 1877b: 476
Salvelinus alipes (Rich.) Gill & Jordan — Bean 1879: 135
Salvelinus nitidus (Rich.) Gill & Jordan — Bean 1879: 135
Salvelinus Hoodii (Rich.) Gill & Jordan — Bean 1879: 135
Salvelinus arcturus (Günth.) Gill & Jordan — Bean 1879: 135
Salvelinus Naresi (Günther) — Bean 1879: 135
Salvelinus stagnalis (Fabricius) — Dresel 1884: 255
— Henn 1932: 1
Salvelinus aureolus — Bean 1887: 628
Salmo marstoni — Garman 1893: 23
Salvelinus alpinus (Linnaeus) — Jordan and Evermann 1896–1900: 508
Salvelinus marstoni — Vladykov 1954: 905
Salvelinus oquassa — Vladykov 1954: 905

Etymology *Salvelinus* — an old name for char; *alpinus* — alpine.

Common names Arctic char, alpine char, Hearne's salmon, sea trout, Hudson Bay salmon, ivitaruk (in fresh water), ekaluk (eqaluk), European char, arctic salmon, arctic charr, trout, Copper-mine River salmon, blueback trout, Greenland charr, Quebec Red trout. French common name: *omble chevalier*.

BROOK TROUT

Salvelinus fontinalis (Mitchill)



Description Body typically troutlike, elongate, average length 10–12 inches (254–305 mm), only moderately laterally compressed, greatest depth at, or in front of, dorsal fin origin, but body depth variable, 20–28% of total length depending upon size, sex, and state of maturity. Head relatively large, 22–27% of total length, eye moderate, its diameter 15–22% of head length; snout somewhat rounded, its length greater than eye diameter, 25–33% of head length; mouth terminal, large, maxillary extending posteriorly to beyond posterior margin of eye, breeding males may develop a hook (or kype) at the front of the lower jaw; well-developed teeth on upper and lower jaws (premaxillary, maxillary, and dentary), on the head of the vomer (not on shaft), on palatines, on tongue (in 2 rows), basibranchial (hyoid) teeth usually lacking. Gill rakers 14–22 (4–7 on upper arch, 10–15 on lower) (*see* Vladykov 1954). Branchiostegal rays 9–13, usually fewer on right side (10–13 on left, 9–12 on right). Fins: dorsal adipose present; principal dorsal rays 10–14; caudal with a shallow fork; principal anal rays 9–13; pelvic rays 8–10, a distinct pelvic axillary process present; pectoral rays 11–14. Scales cycloid, small, in about 230 rows at lateral line, 110–130 pores along lateral line, lateral line straight. Pyloric caeca total range 23–55 but usually less than 50. Vertebrae 58–62.

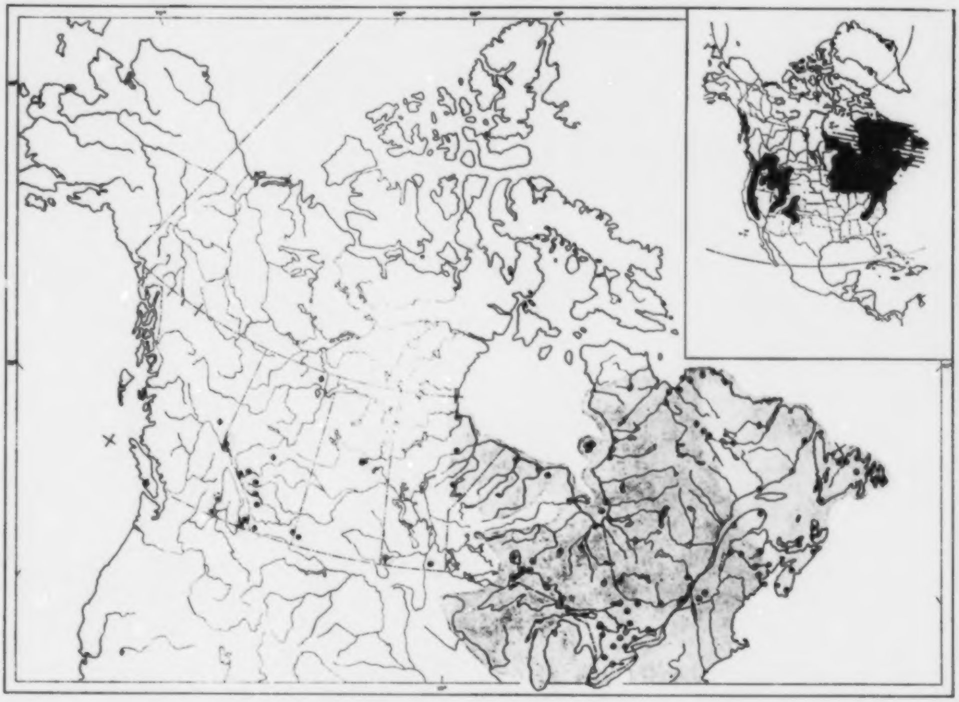
(*See also* Wilder 1952; Vladykov 1954; Bigelow 1963.)

Colour Back olive-green to dark brown, at times almost black, sides lighter, becoming silvery white below; light green or cream coloured wavy lines or vermiculations on top of head and on back, broken up into spots on sides. In addition to pale spots on sides are small discrete red spots surrounded with bluish halos. Dorsal fin with heavy, black, wavy lines, lending a marbled appearance. Caudal fin with variable black lines, sometimes two or three lines parallel to the trailing edge of the fin. Anal, pelvic, and pectoral fins with an immaculate white leading edge usually followed by black pigment and then reddish colouration. All colours intensified at spawning time, lower flanks and belly of males becoming orange-red with black pigmentation on either side of belly.

Sea-run brook trout become silvery with purple iridescence; only red spots are visible on sides. *See* colour illustration facing p. 218.

Systematic notes The brook trout exhibits considerable variation in growth rate, colour, and other features, throughout its range, but generally speaking it is a stable and well-defined species.

The systematic relationship between freshwater and anadromous (sea trout) populations was investigated by Wilder (1952), who also reviewed the nomenclatural history for the sea-run brook trout. Wilder concluded that sea-run brook trout were not taxonomically distinct from freshwater trout. Sea-run trout were long considered to be a species



distinct from the freshwater brook trout and were named *Salmo hudsonicus* by Suckley (1862b). Subsequently Hubbs (1926) designated the sea trout as a subspecies, *S. fontinalis hudsonicus*, but this view has not been substantiated. For additional information and discussion of freshwater and anadromous stocks, *see* Scott and Crossman (1964) and the many papers by Smith and Saunders, especially Smith and Saunders (1967).

Populations of non-speckled or non-spotted brook trout in a restricted portion of the Timiskaming District of Ontario were described by Henn and Rinkenbach (1925) as a distinct species, *Salvelinus timagamiensis*, the aurora trout. In a re-examination of this form, Sale (1967) demonstrated that it was closely allied to *S. fontinalis* and suggested that it be considered a subspecies, *S. f. timagamiensis*. Unfortunately the natural stock has been decimated and it is doubtful that any aurora trout live in any of the lakes from which it was described.

Vladykov (1954) and Slastenenko (1958) apparently favoured retention of *Baione* DeKay (1842) as a subgenus for *S. fontinalis* but this view does not have wide support.

Male brook trout may be crossed with female lake trout to produce a fertile hybrid, often called "splake." For additional information *see Systematic notes* for lake trout. Brook trout can also be crossed with brown trout to produce a so-called tiger trout; *see Systematic notes* for brown trout. An artificial hybrid between brook trout and kokanee (*Oncorhynchus nerka*) was described by Crossman and Buss (1966). *See also* Buss and Wright (1956, 1958) for additional information on hybrids involving brook trout.

Distribution The brook trout is a North American endemic species and under natural conditions occurs only in northeastern North America from the Atlantic seaboard south to Cape Cod, in the Appalachian Mountains southward to Georgia, west in the upper Mississippi and Great Lakes drainages to Minnesota, north to Hudson Bay.

In Canada, the brook trout is widely distributed throughout the Maritime Provinces, including offshore islands, Newfoundland, Labrador, and Quebec, west through the Great Lakes drainage of Ontario, north to James and Hudson bays including the Belcher and Akimiski islands, coastwise to northeastern Manitoba where it occurs in the Nelson and Hayes River systems and north along the Hudson Bay coast to Seal River. In Ontario, it is absent from Lake Attawapiskat and the immediate drainage system although it occurs in the lower reaches of the Attawapiskat River, and from the extreme western portion of the province (*see also* Ryder et al. 1964).

The brook trout has been introduced widely and often successfully into many parts of the world because of its appeal as a sport fish. Included in its extended range are many parts of western North America, South America (including the Falkland Islands), New Zealand, Asia, and many parts of Europe. *See* MacCrimmon and Campbell (1969) for a review of the world distribution of brook trout.

Biology The brook trout spawns in late summer or autumn, the date varying with latitude and temperature. Through southern and eastern Canada spawning occurs usually during late September, October, or November, but it may take place as early as late August in the north and as late as December in the southern part of its Ontario range (Ricker 1932).

Spawning takes place most often over gravel beds in the shallows of headwaters of streams but may be successfully accomplished in gravelly shallows of lakes if there is spring upwelling and a moderate current. In Lake Nipigon, large trout did not enter rivers but spawned on gravel beds near shore in water about 24 inches (61 cm) deep (Ricker 1932). Gravelly shallows of headwater streams with strong springwater flow are particularly favoured. Mature fish may travel many miles upstream to reach the spawning grounds. Males usually arrive first and often outnumber females. Individual males may display some territoriality but their aggressiveness increases when joined by a female. The actual spawning act is performed by one male and one female, but each may spawn with different mates during the reproductive period. The female clears away debris and silt from the nesting area by a series of rapid fanning movements of the caudal fin made while on her side. The circling and courting movements of the male, quite often larger than the female, produces currents which assist in cleaning the area. Both male and female will dart at intruders to drive them away. Spawning occurs during the daytime, in contrast to night spawning by lake trout.

Literature accounts of the spawning act differ, and accounts of the behaviour of hatchery fish, often artificially bred for generations, may not be characteristic of wild trout. In the Mad River, Ont., Ricker (1932) reported ". . . the females turn quickly on either side, give two to four flips of the tail, and the eggs are shot out." On the other hand, Greeley (1932) reported that the female took a position on the bottom of the nest, with pectoral and pelvic fins spread against the stones, at her side, the male arched his body to hold the female against the bottom and both vibrated intensely as eggs and milt were discharged. There are usually several extrusions followed by a resting period. The eggs are adhesive for a short period after extrusion which serves to prevent those not lodged in gravel from being washed away. On completion of spawning, the female covers the eggs with gravel in a manner resembling the excavation of the redd (*see* White 1930; Needham 1961).

The eggs are large, 3.5–5.0 mm in diameter. The number deposited depends upon the size of the female but may vary from 100 for a female 5.7 inches (144 mm) long to 5000 for one 22.2 inches (565 mm) in fork length. For further information on fecundity, *see* Vladykov (1956) who also provided coloured illustrations of dissected females to demonstrate prespawning and postspawning condition of ovaries.

The eggs incubate within the gravel substrate, the total time required depending upon such factors as temperature and oxygen tension. At 41° F (5° C) eggs hatch in about 100 days, at 43° F (6.1° C) in about 75 days, and at 50° F (10° C) in 50 days. The upper lethal temperature limit for developing eggs is about 53° F (11.7° C). When hatched, the larvae or sac fry remain in the gravel within the redd until the yolk is absorbed. They become free swimming when about 1.5 inches (38 mm) long. Scales begin to form when the young are about 2 inches (50 mm) long.

Brook trout can be aged by means of their scales. Scale samples are usually taken from above the lateral line, between the dorsal and the adipose fins.

The rate of growth varies greatly throughout the native range, depending upon local conditions. Brook trout may overpopulate small streams, resulting in a large number of small trout less than 10 inches (254 mm) long. Unlike lake trout or arctic char, the brook trout is relatively short-lived and wild trout seldom live longer than 5 years, and never beyond 8 years. In California, introduced trout are said to live to 15 years (McAfee 1966). Sexual maturity is usually attained at age 3, but some individuals may mature at age 2 (Cooper 1940; Baldwin 1948).

The maximum size for brook trout was a 14.5-pound (6.6-kg) specimen caught in Rabbit Rapids, Nipigon River, Ont., in 1915, by Dr J. W. Cook of Fort William. From time to time rumours of larger brook trout are circulated but none have proved to be true. Recently a report of a 19.5-pound trout caught in a lake north of Goose Bay, Lab., reached our notice. The specimen proved to be an arctic char, not a brook trout. A number of brook trout weighing 5–6 pounds are caught each year. The largest entered in the Ontario Federation of Anglers and Hunters Big Fish Contest during 1968–1970 weighed 7 pounds 5 ounces, but there were many in the 6-pound class. Fish over 10 pounds are rare and few have been reported in recent years. Comparative rates of growth for populations from across Canada follow:

		Age (*years*)							
		0+	1+	2+	3+	4+	5+	6+	7+
	SL								
sea-run	*inches*	–	–	7.9	9.7	10.8	13.2	15.6	–
Moser R., N.S.	*mm*	–	–	201	247	274	334	396	–
(Wilder 1952)									
	SL								
freshwater	*inches*	1.5	4.3	6.2	7.0	8.8	10.8	–	–
	mm	39	109	156	178	224	274	–	–
	FL								
Matamek L.	*inches*	1.5	3.5	4.9	6.8	8.4	9.9	11.6	13.3
Saguenay Co., Que.	*mm*	38	88	124	172	212	251	294	337
(Saunders and Power 1969)	Wt (*oz*)	-	0.3	0.8	2.1	3.9	6.6	10.9	–
	TL								
Red Rock L., Ont.	*inches*	1.4	6.1	9.1	11.7	14.8	17.4	–	–
(Baldwin 1948)	*mm*	36	155	231	297	376	442	–	–
	TL								
Nelson &	*inches*	–	–	11.6	15.2	17.3	19.1	20.9	–
Hayes R., Man.	*mm*	–	–	295	386	439	486	531	–
(& tributaries)	Wt (*oz*)	–	–	7.5	20.5	29.9	43.6	57.0	-
(Doan 1948)									
	FL								
Pyramid L., Alta.	*inches*	–	5.4	8.6	11.1	14.0	16.5	–	–
(Rawson and	*mm*	–	137	218	282	356	419	–	–
Elsey 1950)	Wt (*oz*)	–	1.5	5.5	10.5	22.0	34.0	–	–

The brook trout, or speckled trout as it is more frequently called in Canadian literature, has been widely used as an experimental animal and, hence, there is much information in the literature on many aspects of its biology not mentioned above (*see* Brown 1957a; Shepard 1955; Job 1955; under *Suggested Reading* section for pertinent literature).

Brook trout occur in clear, cool, well-oxygenated streams and lakes. They tend to seek temperatures below 68° F (20° C) when surface waters warm up. In Red Rock Lake, Algonquin Park, Ont., Baldwin (1948) observed that brook trout moved to depths between 15 and 27 feet (4.6–8.2 m) during July and August. In streams and rivers brook trout move downstream to larger bodies of water when temperatures rise and may move completely out of the river system into lake or sea. In the northern part of its range, the brook trout may remain in rivers throughout the summer, as in Ungava, Que. (Power 1966), or they may leave the streams and go to sea as they do in many Hudson Bay tributary streams in Ontario, Quebec, the Maritime Provinces (Smith and Saunders 1958, 1967) and Newfoundland (Scott and Crossman 1964).

Brook trout are carnivorous, and feed upon a wide range of organisms, although stomachs sometimes contain traces of plant remains. Young and medium-sized trout eat large numbers of aquatic insect larvae and terrestrial insects. In a very thorough study of brook trout in Ontario, Ricker (1932) provided also a review of the organisms eaten. The list of organisms is astonishing and suggests that brook trout will eat any living creature its mouth can accommodate: worms, leeches, crustaceans (cladocerans, amphipods, decapods), aquatic insects (over 80 genera eaten but mayfly, caddisfly, midge, and blackfly larvae common), terrestrial insects (over 30 families, ants sometimes in abundance), spiders, molluscs (including clams and snails), a number of fish species, including young brook trout and brook trout eggs, minnows, sticklebacks, and cottids, frogs, salamanders, and a snake (in a 7-inch trout). Although not mentioned by Ricker, larger trout, particularly in northern waters during summer, are known to eat numbers of small mammals, mainly the field mouse, *Microtus*, but also the redback vole, *Cleithrionomys*, and shrews. Sea-run trout eat invertebrates and fishes found in marine and brackish waters.

In a study of food consumption and growth, Baldwin (1957) observed that brook trout weekly ate 50% of their own weight (in minnows) at 55.4° F (13° C) but less than this amount at 48.2° F (9° C) and 62.6° F (17° C).

Brook trout engage in a limited amount of cannibalism, eating their own eggs at spawning time and their own young in spring (Ricker 1932; White 1924). White also noted that young trout were eaten by rock bass. Possibly the most serious predators are fish-eating birds, such as kingfishers and mergansers, whose brook trout eating habits have been documented by White (1936, 1937, 1938, 1953, 1957) for the Maritime region.

Long interest in brook trout as a hatchery-reared and pond-cultured sport fish has resulted in the accumulation of much information on its parasites.

Lyster (1940a) discussed parasitism of brook trout in Lake Commandant, Que. He reported three trematodes, one, *Ptychogonimus fontanus*, in considerable quantity in the stomach and upper digestive tract. Cestodes, especially the large tapeworm *Eubothrium salvelini*, light infections of the acanthocephalan *Neoechinorhynchus cylindratus*, and two species of nematodes were also reported. Lyster (1940b) also reported black-spot caused by the trematode *Apophallus brevis*.

Bangham and Hunter (1939) found light infections of the nematode *Cystidicloides harwoodi* only, in 40 of the 63 specimens they examined from the upper portions of streams flowing into Lake Erie.

MacLulich (1943b) studied parasitism of trout in Algonquin Park, Ont., and reported that microsporidian parasites, forming white cysts in the kidneys, were abundant in both lake and brook trout, the abundance differing with locality. He also reported small numbers of the trematode *Crepidostomum farionis* in the intestines of a few trout, and the unusual occurrence of two flukes, *Crepidostomum*, in the gall bladder of one trout from Red Rock Lake. Black-spot occurred on pectoral fins of some trout from Proulx and Red Rock lakes. The cestode *Diphyllobothrium* sp. was absent from brook trout he studied, but *Eubothrium salvelini* occurred in 66% of specimens examined and *Proteocephalus parallacticus*, a new species of tapeworm (MacLulich 1943a), and *P. ambloplitis* were also reported. Infestation by roundworms, *Cystidicola stigmatura*, was heavy but did not appear to seriously affect the hosts. *See* MacLulich (1943b) for detailed list.

Bangham and Venard (1946) reported several of the species of parasites reported by MacLulich, but added *Hepaticola bakeri* and *Contracaecum brachyurum*. In Lake Huron waters Bangham (1955) reported light infections only.

See Choquette (1948) for incidence of internal helminths in speckled trout in Laurentide Park, Que., and also Choquette (1955) for common occurrence of the nematode, *Metabronema salvelini*.

All nine specimens examined from Flynn Lakes, Gatineau County, Que., contained *E. salvelini* (Worley and Bangham 1952).

In British Columbia, where brook trout is an introduced species, Bangham and Adams (1954) reported it had fewer parasites than native forms, and stated that all parasites identified were of scattered occurrence, except *Crepidostomum farionis* (in 64% of the 110 specimens examined), *Metabronema salvelini* (22%), and *Bulbodacnitis globosa* (15%).

Mortalities of brook trout have been reported caused by acanthocephalans (Pippy and Sandeman 1967) and leeches (Rupp and Meyer 1954).

Ulcer disease and furunculosis may cause considerable loss of hatchery stock. *See* Snieszko (1952), McCraw (1952), Davis (1953), and Margolis (1954).

Relation to man The brook trout is a most highly esteemed game fish and one of the most popular game fishes in eastern Canada. It is fished by artificial fly, spin casting, or live bait. Since it is classed as a game fish, commercial sale for food is illegal in Ontario, but not everywhere in Canada.

Rearing brook trout in hatcheries has been practised for decades. In addition to government hatcheries, many private producers sell hatchery fish (fry, fingerlings, yearlings) for stocking private ponds. Many private trout clubs maintain their own brood stock, hatcheries, and rearing ponds, and offset some of their overhead by offering surplus stock for sale to other clubs.

For information on pond culture and practices, *see* Ayers et al. (1963), Cooper (1959), Eipper (1964), and Séguin (1955).

Nomenclature

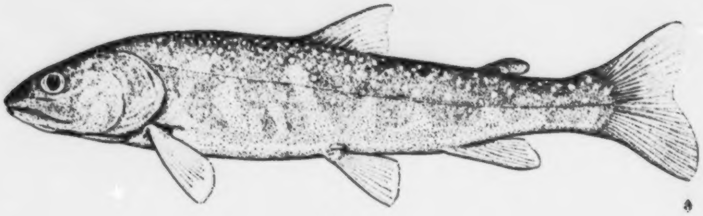
Salmo fontinalis — Mitchill 1815a: 435 (type locality vicinity New York City, N.Y.)
Salmo canadensis — Smith (*in* Cuvier 1834: 474)
Salmo immaculatus — Storer 1857: 264
Salmo hudsonicus — Suckley 1862b: 310
Salvelinus fontinalis — Jordan and Copeland 1878: 430
Baione fontinalis — Slastenenko 1958: 82
Salvelinus timagamiensis Henn and Rinkenbach — Scott and Crossman 1967: 8

Etymology *Salvelinus* — an old name for char; *fontinalis* — living in springs.

Common names Brook trout, Eastern brook trout, speckled trout, aurora trout, brookie, square-tail, speckled char, sea trout, common brook trout, mud trout, coaster, eastern speckled trout, native trout, mountain trout, breac, squaretailed trout. French common names: *omble de fontaine, truite, truite de mer, truite mouchetée.*

DOLLY VARDEN

Salvelinus malma (Walbaum)



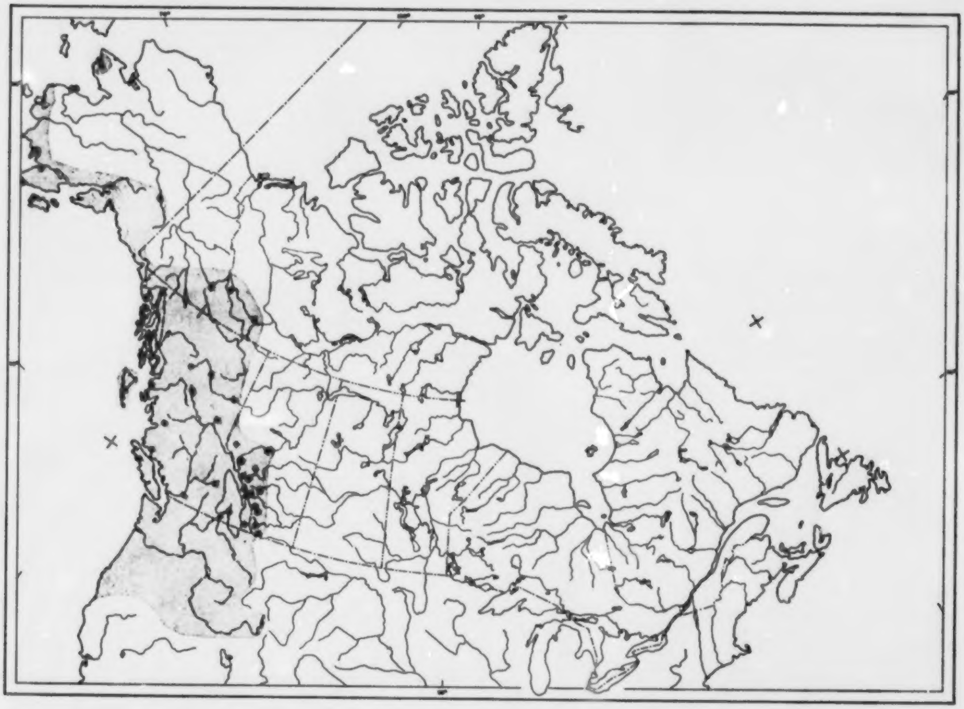
Description Body elongate, troutlike, average length variable, that of freshwater forms 12–18 inches (305–457 mm) and anadromous stocks 18–24 inches (457–610 mm), somewhat rounded, greatest body depth below dorsal fin about 20% of total length. Head rather long, about 15–28% of total length; eye large, 20–22% of head length; snout a blunt point, long, almost twice eye diameter; mouth terminal, large, maxillary to posterior edge of eye and often far beyond, kype well developed in breeding males of some anadromous populations; well-developed teeth on both jaws (premaxillary, maxillary and dentary, may extend almost to tip of maxillary), head of vomer (not on shaft), palatines (often joined to those on vomer), tongue (7–15), teeth on basibranchials variable with length, 0–44. Gill rakers moderate, 11–26, usually 3–9 on upper limb and 8–14 on lower limb. Branchiostegal rays 10–15 (10–15 + 11–15). Fins: slender, long dorsal adipose present; dorsal 1, at middle of body, not high nor long, 10–12 major rays (all rays 13–16); caudal broad, shallowly forked, tips rounded to pointed; major anal rays 9–11 (all rays 11–15); pelvics abdominal, not long, square, 9–11 rays; pectorals moderate, square, 14–16 rays. Scales cycloid, small, pored scales along lateral line 105–142; lateral line slightly decurved anteriorly, then straight, often with dip or arch posteriorly. Pyloric caeca 13–47 (19–47 in northern and southern populations, 13–18 in central Alaska). Vertebrae 57–70.

(*See also* Bajkov 1927; Dymond 1936; DeLacy and Morton 1943; and McPhail 1961, for proportional measurements and details of description.)

Colour Variable with size, locality, and habitat. Sea-run adults with back, upper head, and upper sides dark blue, the sides silvery, ventral surface silvery to white. In freshwater populations the back and upper sides are olive-green to brown, the sides a paler colour but bright red in spawning fish and at all times in some areas of Alaska, the underside white to dusky. The dorsal surface and sides are marked with yellow, orange, or red spots, more numerous and those along the lateral line smaller, than arctic char. The spots are usually smaller than the pupil of the eye; back occasionally with vermiculations. The paired fins and anal fin are white, or creamy on leading edge with a single thin black and thin red line behind. Dorsal and caudal fins dusky to brownish, sometimes with a few pale spots.

The young and some dwarf populations have 8–12 irregular, dark parr marks which are mere dark blotches in fish less than 3 inches (76 mm). There is fine dark speckling on the lower sides, and the dorsal and adipose fins are dusky but without spots.

Spawning males, especially of anadromous populations, turn red on the ventral surface and tip of snout. The lower jaw, operculum, and parts of the head are black, the back and sides turn olive-brown. The spots become a more vivid orange-red, the pectoral, pelvic, and anal fins red-black with a white leading edge, the snout thickens and the lower jaw turns up. Females change less.



Systematic notes The Dolly Varden was originally described by Walbaum as a distinct species, *Salmo malma*. There are a number of early synonyms (*see* La Rivers 1962; Morton 1970). In 1909 Berg suggested that it was not distinct from the arctic char, and gave it subspecies status calling it *Salvelinus alpinus malma*. It was variously known as a species and subspecies over the years. Jordan et al. (1930) considered it distinct and mentioned two subspecies, *S. m. malma* and *S. m. spectabilis*. At least until recently, Russian workers recognized two subspecies in Asia, *S. m. malma* and *S. m. krascheninnikovi*. McPhail (1961) said there were two distinct forms in North America, north of the Alaska Peninsula (65–71 vertebrae, 11–41 lower limb gill rakers), and south of the Alaska Peninsula (57–67 vertebrae, 8–12 lower limb gill rakers). He did not give them names, and Morton (1970) was convinced all subspecific names for *S. malma* in North America should be suppressed.

The documentation of the species status of the Dolly Varden, at least in North America, was given in detail by DeLacy and Morton (1943), and McPhail (1961). *Salvelinus parkei*, a form commonly placed in the synonymy of this species, is considered by some distinct.

The common name of this fish is probably the only one made up of the Christian name and surname of a fictitious, literary character. It is, therefore, the only one in North America regularly spelled with capital letters. Dolly Varden was a gaily dressed, young woman in Dickens' novel "Barnaby Rudge." During a visit by Dickens to North America a pink-spotted calico material became very popular and was called Dolly Varden. A woman is supposed to have seen *S. malma* during this period and referred to it as a Dolly Varden trout (Dymond 1932c).

Distribution This species is found in the fresh and salt water of western North America and eastern Asia. It occurs from the

McCloud River in northern California, western Montana, and isolated streams in Nevada and Idaho (nonmigratory populations), north to Seward Peninsula, Alaska. On the Asian side it occurs from the Anadyr River, USSR, south to the Yalu River, Korea.

In Canada it occurs from the headwaters of the South Saskatchewan River in Alberta, northwest through all but extreme northeastern British Columbia and the Okanagan River system, on Vancouver and Queen Charlotte islands, and in the headwaters of the Yukon, Liard, Nahani, Peace, and Athabasca rivers. Dolly Varden are common in central Yukon Territory and present in the extreme southwestern part of the Northwest Territories. Records from other Mackenzie River tributaries, and from the arctic coast, may actually be arctic char.

There are anadromous and nonanadromous populations from Washington north but the California, Nevada, Montana, and Idaho populations are freshwater only. The anadromous fish apparently do not move out into the open ocean but remain close to shore near the river mouths.

Biology Most of the detailed work on the biology of this species has been carried out in Alaska. Works by Armstrong (1965), Heiser (1966), Blackett (1968), and an annotated bibliography by Armstrong and Morton (1969) provide most of the information.

Like other chars, the Dolly Varden is a fall spawner. It spawns in different areas from September to early November (usually October). Anadromous fish migrate from the sea and enter river mouths from May to December (usually August to September). There is a strong homing tendency. Spawning populations of large lakes move into inlet rivers at about the same time. Secondary sexual characteristics do not develop until anadromous fish have been in fresh water for some time. Spawning takes place during the day, and to a lesser extent at night, in rivers of moderate current with a bottom of medium to large gravel, and at water temperatures near 46° F (7.8° C).

On the spawning grounds males are aggressive, charge, nip, and drive other males away from the redd. The redd is dug by the female usually with the up-and-down action of tail but in some non-anadromous populations observers have suggested that it is with a side-to-side motion. This unusual action may be part of post-spawning behaviour. Redds are usually 12–24 inches (305–610 mm) in diameter, at times as much as 12 inches (305 mm) deep, and usually at least 20 feet (6.1 m) apart. A female is often attended by as many as four or five males, but a larger one is usually dominant. There is prespawning courtship of body pressing and quivering. Sex products are released when the female and one or more males swim into the nest, press closely together, arch their backs, vibrate and the mouths gape. (*See also* Needham and Vaughan 1952.)

Egg number in females may be as high as 8000 in Montana, but differs by area and for anadromous and non-anadromous stocks. Averages were between 1337 and 8845 in Montana and 1336–3387 in Alaska. The mature eggs are usually 4.5–5.5 mm in diameter, orange-red, and demersal. After spawning the female covers the nest by digging at the upstream end and displacing gravel into it. The adults are in poor condition after spawning and move down to the lake to spend the winter there.

Early development of the eggs and young was given in detail by Blackett (1968). Most hatching occurs in the spring, March to April, or about 4½ months after spawning. The alevins are about 18.2–19.4 mm at hatching. They usually spend about 18 days in the gravel, emerging in late April to mid-May when the yolk is nearly used up, when they are about 20–25 mm in length. They are very inactive at first and remain quiet on the bottom but soon commence active feeding. Growth is rapid at first, slowing in later years. Young-of-the-year in Alaska are 1.2–1.8 inches (32–47 mm) long in October and juveniles found in streams are usually 1.0–5.9 inches (20–150 mm) in length. The following table gives the age–length relation for four localities.

The table indicates a decrease in growth rate toward the north. The 1927 figures for

		Age (*years*)											
	FL	0	1	2	3	4	5	6	7	8	9	10	11
Eva Creek, Alaska	*inches*	0.8–1.7	2.0–2.9	2.4–4.0	3.4–4.1	8.1	9.8	12.4	14.6	15.5	18.7	17.0	17.1
(anadromous)	*mm*	21–44	50–74	61–100	86–106	206	249	315	372	394	476	433	435
Heiser (1966)	Wt (*lb*)	–	–	0.02	0.06	0.16	0.28	0.57	0.90	1.06	1.88	1.46	1.05
Bow R., Alta.	*inches*	–	6.5	8.3	9.7	10.6	12.6	13.2	–	–	15.9	–	–
Miller (1949)	*mm*	–	165	211	246	269	320	335	–	–	404	–	–
	Wt (*oz*)	–	2.0	3.5	5.6	7.6	12.0	13.0	–	–	24.0	–	–
Jasper National Park, Alta.	*inches*	2.3–2.9	–	7.8–9.0	9.8–11.8	13.0–15.7	16.2–18.1	19.7–21.2	22.0–24.4		–	–	–
Bajkov (1927)	*mm*	60–75	–	200–230	250–300	330–400	410–460	500–540	560–620		–	–	–
Upper Campbell L., Vancouver Island, B.C.	*inches*	–	9.1	9.4	11.4	–	–	–	–	–	–	–	–
McMynn and	*mm*	–	231	239	290	–	–	–	–	–	–	–	–
Larkin (1953)	Wt (*oz*)	–	4.2	5.0	9.5	–	–	–	–	–	–	–	–

Jasper National Park were, in the original, given at half year intervals, and other than year 0 have been set back here. Unless the growth rate in that Jasper Park lake was phenomenal this alignment seems more logical. The Eva Creek, Alaska, population is anadromous and goes to sea after 3 or 4 years in fresh water. The increase in length between years 3 and 4 as a result of this is about 4 inches (102 mm), and they almost double their weight. In non-anadromous populations the young may spend from several months to 3–4 years in streams, moving then to a lake, just as the anadromous stocks move to sea.

Sexual maturity is reached in years 3–6 in both types of populations. Males often mature a year earlier than females. In the northern part of the range not all adults migrate or spawn every year. At least some fish spawn every year from year 6 to year 10 or 11. Maximum size varies with location and between anadromous and non-anadromous stocks. Dolly Varden apparently grow to 50 inches (127 cm) length and 32 pounds weight according to McPhail and Lindsey (1970) but some anadromous populations reach only 5½ pounds, and maximum weight in Alberta has been given as 14 pounds 13 ounces. Inland, high-altitude and northern populations are often stunted and do not exceed 12 inches (305 mm) in length. The angler record is given by *Field and Stream* magazine as 40½ inches (102.9 cm) length, 29¾ inches (755 mm) girth, and 32 pounds weight. This fish was caught in Lake Pend Oreille, Idaho, in 1949. It may be the fish referred to by Paetz and Nelson as 50½ inches (128.3 cm) and McPhail and Lindsey as 50 inches (127 cm). Several just over 28 pounds have been taken by sportsmen in Kootenay Lake, B.C.

Ages to 20 years in California have been given (Carlander 1953) but 10–12 years would seem to be more usual over the whole range.

Habitat of the young for 3–4 years is the gravelly spawning stream in which they were spawned. They apparently move about over the length of these streams. The adults are found in cold lakes, gravelly to rather muddy (Peace River area) rivers, and in the sea. Anadromous stocks migrate seaward out of the lakes or rivers in late May to early June. They spend anywhere from 60 to 160 days in the sea, moving only short distances from the river mouth or staying in tidal water. They move back into the rivers from May to December, but usually in mid-July to September.

Summer food of stream-resident young is apparently made up largely of adult and immature insects, snails, and leeches. Salmon eggs and insects are important in the fall. The Dolly Varden has long enjoyed the reputation of a serious, or the most serious, predator on young salmon and a bounty was long paid on Dolly Varden in Alaska. This predaceous habit has led to at least 47 published studies of its food (*see* Pritchard

1936; Roos 1959; Lagler and Wright 1962; Narver and Dahlberg 1965) and overall, the Dolly Varden does not seem any worse than cutthroat trout, coho salmon smolts, or sculpins. In certain areas and especially at time of downstream migration of young salmon it consumes large numbers of salmon even when 5–6 inches (127–152 mm) in length. In May and June at Cultus Lake, individuals often have eaten as many as 90 sockeye salmon each. In the sea, young salmon are about fourth in importance as food, capelin and sand lance constituting 85% of the food volume. In general, food of Dolly Varden at Chignik, Alaska, consisted, in order of percentage occurrence in fish which contained food, of caddisfly larvae, dipterous larvae, sockeye fingerlings, dipterous adults, isopods, fish remains, caddisfly pupae, sculpins, and salmon eggs. Various other fishes such as sand lance, smelt, blackfish, sticklebacks, and a variety of invertebrates such as stoneflies, beetles, amphipods, ostracods, spiders, gastropods, earthworms were also present. In estuaries, whitespotted greenling, silverspotted sculpin, euphausiids, salmon offal, polychaete worms, and herring have been reported. In the interior of British Columbia they eat peamouth, kokanee, and mountain whitefish. Withler (1948) reported that in some years they ate significant numbers of red-backed mice in the Skeena River, Ricker (1933) reported them gorging on the remains of dead Pacific salmon, and Dymond (1932c) included moles, frogs, and birds.

The larger young and the adults are obviously competitors with other salmonids for food. Fall spawning adults compete with Pacific salmon but not trout for spawning grounds. Little is known of fishes which prey on the Dolly Varden.

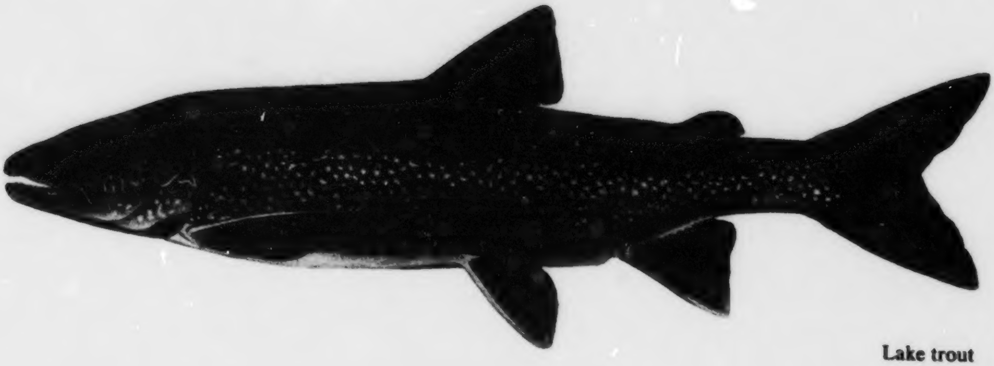
Bangham and Adams (1954) found all 51 specimens of this species which they examined from nine locations in British Columbia contained parasites. They reported that the trematode *Crepidostomum farionis* and acanthocephalan *Neoechinorhynchus rutili* were present in 69% of the Dolly Varden from all but two locations. The cestode *Eubothrium salvelini* occurred in 20% of the Dolly Varden and, with one exception, in all locations sampled. *See* Bangham and Adams (1954) for other marine and freshwater parasites identified. Margolis (1967b) studied a collection of this species from the Kitimat River, B.C., and identified the nematode *Salvelinema salminicola* in the swim bladder. Reed (1967) reported Dolly Varden infected with black-spot, the copepod *Salmincola* sp.; the nematode *Eustrongylides* sp.; and the roundworm *Philonema* sp. from Old Tom Creek, southeastern Alaska. Furunculosis has apparently caused serious losses in Dolly Varden populations.

Hoffman (1967) listed the following parasites for this species in North American fresh waters: trematodes (8), cestodes (7), nematodes (7), acanthocephalans (4), crustaceans (5). He also listed parasites from Russia.

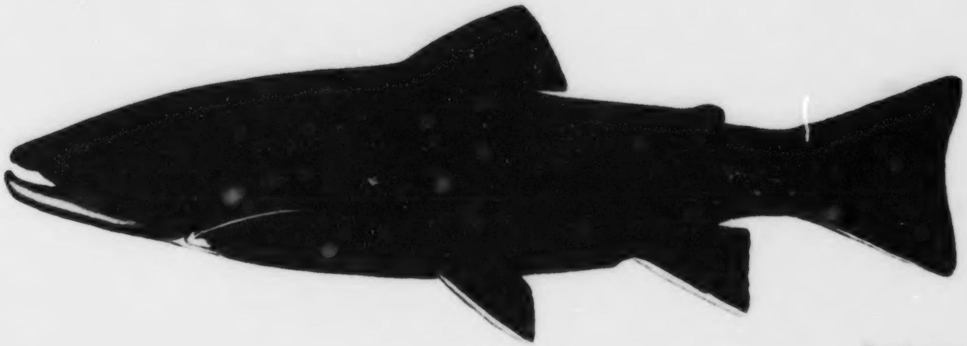
Dolly Varden may hybridize with brook trout in Alberta.

Relation to man The most important relation to man of the Dolly Varden was long considered to be its extensive destruction of salmon and trout which were more valued than it was. As a result of this reputation in Alaska, a bounty of 2½ cents each was paid, and they were destroyed by the thousands when taken in traps and weirs. Up to 20,000 dollars a year were spent on bounties in the 1930's. This charge may have been overdone according to McPhail and Lindsey (1970). However, according to Foerster and Ricker (1942), reducing the number of Dolly Varden and squawfish in Cultus Lake, B.C., was calculated to have "saved" 3.8 million migrant sockeye salmon which, according to their calculations, would yield an additional return of 38,000 adult sockeye. The controversy is probably not ended.

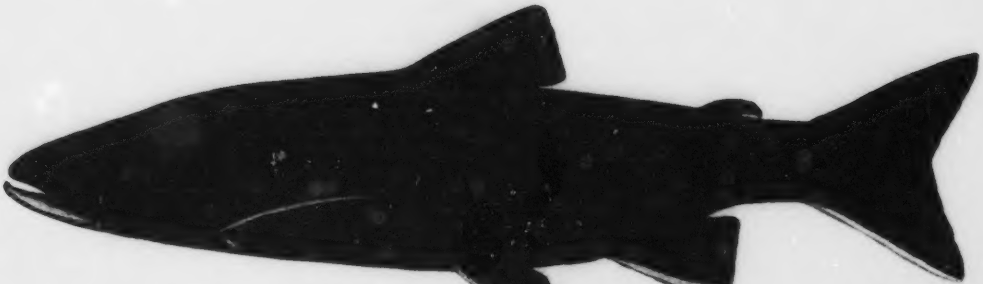
As a sport fish, the Dolly Varden will take most artificial lures and smaller ones can be taken by fly fishing. Although they can constitute a quarry of large size, they do not have the sporting qualities of other trouts and, although popular in eastern B.C., are not looked upon with much favour by anglers, except where other trout are not abundant. It is somewhat more popular in Montana, Idaho, and Alaska. They were at one



Lake trout



Brook trout



Arctic char

time taken incidental to catches of other fishes in Alaska, processed as fresh, fresh-frozen, canned, or dried fish, and sold commercially. In Kootenay Lake, B.C., up to 1930, a few Dolly Varden were caught for sale to hotels in Nelson, B.C. Since 1950 the sportsmen's catch of this species has steadily increased.

Nomenclature

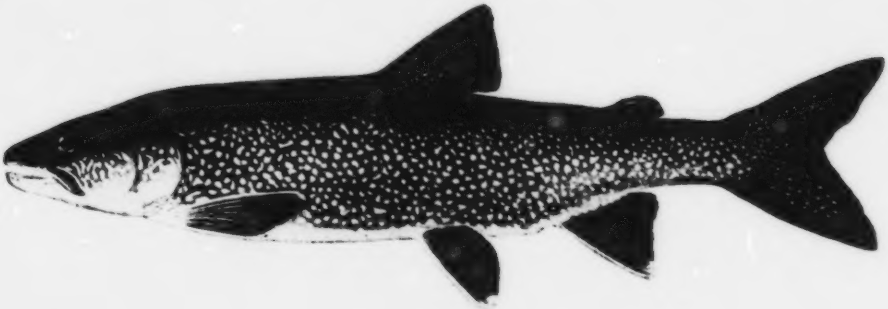
Salmo Malma — Walbaum 1792: 66 (type locality rivers of Kamchatka Peninsula, Siberia)
Salmo spectabilis — Girard 1857b: 218
Salmo bairdii Suckley — Suckley 1862b: 309
Salmo parkei Suckley — Suckley 1862b: 310
Salmo Campbelli, nob. — Suckley 1862b: 313
Salmo parkii — Günther 1866: 121
Salmo lordii — Günther 1866: 148
Fario Lordii — Lord 1867:
Salmo tudes — Cope 1873: 24
Salvelinus spectabilis — Jordan 1878c: 79
Salvelinus bairdii — Jordan 1878c: 82
Salvelinus malma — Bendire 1882: 86
Salvelinus namaycush — Eigenmann 1895: 115
Salvelinus parkei — Jordan and Evermann 1908: 210
Salvelinus alpinus malma (Walbaum) — Bajkov 1927: 383
Salvelinus malma spectabilis (Girard) — Jordan, Evermann, and Clark 1930: 61
Salvelinus malma (Walbaum) — Dymond 1932c: 37
Salvelinus malma tudes — Morton 1970: 585

Etymology *Salvelinus* — an old name for char; *malma* — the common name of this species in Kamchatka.

Common names Dolly Varden, Dolly Varden char or charr, trout, bull trout, red-spotted Rocky Mountain trout, red spotted trout or char, Pacific or western brook char or brook trout, sea trout or char, salmon-trout. French common name: *Dolly Varden.*

LAKE TROUT

Salvelinus namaycush (Walbaum)



Description Body typically troutlike, elongate, total length usually 15–20 inches (381–508 mm), somewhat rounded, greatest body depth under, or in front of, dorsal fin origin, 18–26% of total length, variable, dependent upon age, sex, and state of maturity. Head stout, broad dorsally, its length about 21–28% of total length; eye relatively small in adults, 12–20% of head length; snout long, its length greater than eye diameter, 26–36% of head length; mouth large, terminal, snout usually protruding slightly beyond lower jaw when mouth closed, maxillary extending beyond posterior margin of eye on specimens 8 inches (203 mm) or longer; premaxillaries forming tip of snout sometimes enlarged and almost beaklike on large fish; teeth developed on upper and lower jaws (premaxillary, maxillary, and dentary), on head of vomer only (not on shaft), palatines, tongue (in 2 rows), and on basibranchial (hyoid). Gill rakers, total range 16–26 (*See* Martin and Sandercock 1967). Branchiostegal rays total range 10–14 (11–14 + 10–13), usually fewer on right side. Fins: dorsal adipose present; dorsal 1, major rays 8–10; caudal distinctly and deeply forked; major anal rays 8–10; pelvic rays 8–11, pelvic axillary process present but small; pectoral rays 12–17. Scales cycloid, small, pores along lateral line 116–138, lateral line slightly decurved anteriorly, then straight. Pyloric caeca 93–208, the number apparently increases with increase in size but 85% of counts fall within range of 120–180 caeca. Vertebrae 61–69.

Nuptial tubercles minute, present on scales around anal opening of males and females (Vladykov 1954).

See also Vladykov (1954), Qadri (1967), McPhail and Lindsey (1970).

Colour Overall colouration light spots on a darker background and light below. The whole body, including head, dorsal, adipose, and caudal fins, covered with innumerable light-coloured spots on a background colour that varies from light green or gray, to dark green, brown, or almost black. The background colour varies greatly, and trout in large lakes are sometimes so silvery that the spots are difficult to see. The spotting usually more intense on small fish, (under 5 pounds). Red spots are absent on lake trout but orange or orange-red colouration may be evident on pectoral, pelvic, especially anal, and sometimes caudal fins. Such fin colouration is more apparent on populations in northern Canada. Narrow white border sometimes present on anterior margin of pectoral, pelvic, and anal fins but never as wide or immaculate as on *Salvelinus fontinalis*. Young lake trout have distinctive parr marks, about 7–12 in number, but most variable and frequently interrupted; the parr marks are narrow, the interspaces being equal to, or greater than, the width of the parr marks. *See* colour illustration facing p. 218.

Systematic notes The description of the lake trout is usually credited to Walbaum (1792), based on a description of a specimen from the Hudson Bay area which he called *Salmo namaycush*. However, the nomenclatural history is under review by N. V. Martin and further discussion must await the results of his studies.

Although the specific distinctness of the lake trout from other chars is generally accepted, the generic placement has been often in the literature and some authors (particularly Vladykov 1954, 1959, and his former students) preferred to employ *Cristivomer* as the generic name. For further information on this question *see* Kendall (1919), Morton and Miller (1954), Vladykov (1963), and Lindsey (1964). We prefer to place the lake trout with the other chars in the genus *Salvelinus*, in agreement with McPhail and Lindsey (1970).

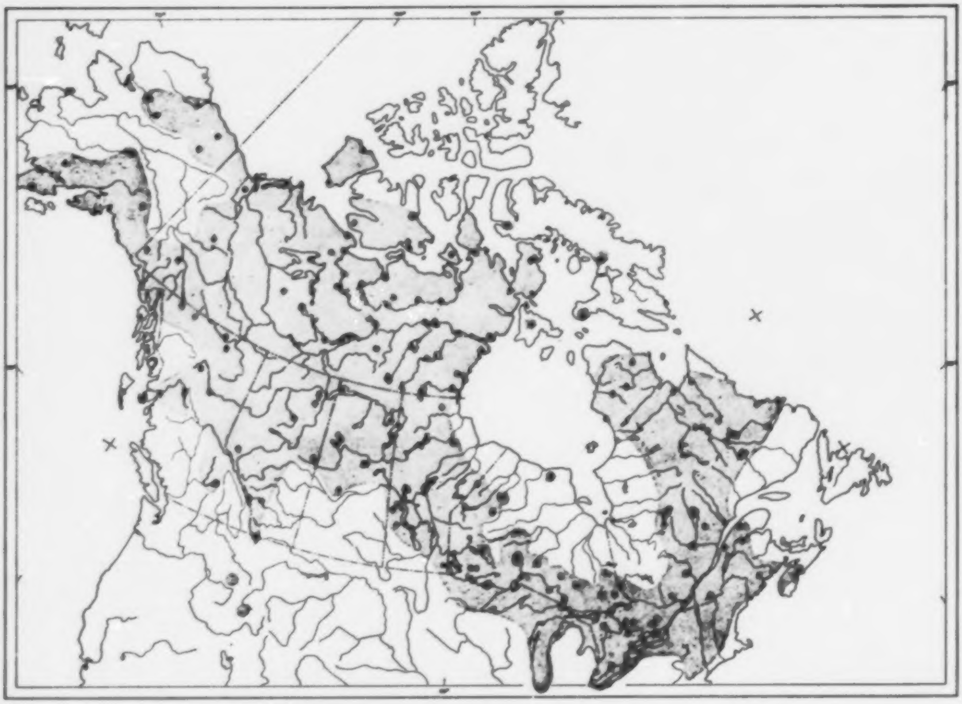
A form of the lake trout found in the deep waters of Lake Superior is called a siscowet and is sometimes regarded as a subspecies, i.e., *Salvelinus namaycush siscowet* (Agassiz). The siscowet is exceedingly fat and was said to spawn at depths over 300 feet (91.4 m). However, all forms of intergrades occur between typical lake trout and siscowets in Lake Superior, which had a number of apparently distinct subpopulations of trout. For further information *see* Eddy and Surber (1960), Eschmeyer and Phillips (1965), Rahrer (1965), Khan and Qadri (1970).

The lake trout has been hybridized quite successfully with the brook trout to produce a fertile hybrid called a "wendigo" or "splake" (from *sp*eckled and *lake* trout). This hybrid is produced by fertilizing lake trout eggs with brook trout sperm. Splake have been planted in many parts of North America but particularly in Ontario, where a selective breeding program is conducted. The hybrid has been introduced into the Great Lakes where individuals have been recaptured 5 and 6 years after planting, some weighing up to 16 pounds. They grow more quickly than either parent, have an omnivorous diet which includes plankton and aquatic insects and so resembles the brook trout, and are known to live for at least 9 years. Splake reach maturity in about 3 years. They tend to spawn during both night and day, although lake trout spawn at night and brook trout during the day. They are intermediate in appearance and characters between the two parents, but usually lack the deeply forked tail or caudal fin of the lake trout. They can be positively identified by the number of pyloric caeca which is intermediate: brook trout 23–55; lake trout 93–208; splake 65–85. Christie (1960) gave a vertebral range for the hybrid of 56–66. For further information *see* Stenton (1950, 1952), Scott (1956), Budd (1957a, 1959), Christie (1960), Martin and Baldwin (1960), Tait (1970).

Distribution The lake trout is of natural occurrence and widely distributed only in northern North America, but it has been introduced elsewhere. Its natural North American range coincides most closely with the limits of Pleistocene glaciation (Lindsey 1964). Even within the general range, its distribution pattern exhibits peculiar clustering in certain regions and complete absence from others that appear equally suitable. Details of its biology and distribution are under critical study by N. V. Martin.

In the United States, the lake trout occurs in the New England states, the Great Lakes states of New York, Pennsylvania, Michigan, Wisconsin, and Minnesota, the western states of Montana, Idaho, and Alaska.

In Canada, the lake trout occurs in southwestern Nova Scotia, New Brunswick, north throughout Quebec and many parts of Labrador, west throughout Ontario but not generally through the Hudson and James Bay lowlands, through northern Manitoba and Saskatchewan, in the southwestern and northeastern portions of Alberta and northern British Columbia, widely distributed in the Yukon and Northwest Territories and also established on many arctic islands (Baffin,



Southampton, King William, Victoria, and Banks).

The lake trout has been introduced widely outside its natural range to such countries as New Zealand, South America, Sweden, and many parts of the United States. *See* Marshall and Keleher (1970) for a partial listing of introductions.

Biology A considerable fund of information has accumulated on lake trout reproduction in Canadian lakes. Lake trout spawn in the autumn but there is much variation from lake to lake and the exact date of spawning depends on such factors as latitude, weather, and the size and topography of the lake. For detailed information resulting from studies on particular lakes *see* Eschmeyer (1955), Martin (1955, 1957, 1960), McCrimmon (1958), and Rawson (1961). Throughout most of Canada, spawning occurs mainly in October, sometimes as early as September in the north or as late as November in the south; in Lac la Ronge, Sask., October 1–11 (Rawson 1961), and in lakes in Algonquin Park, Ont., October 15–31 (Martin 1957). In New York State spawning may be delayed until early December. Dates of spawning in different parts of North America were tabulated by Martin (1957).

Spawning most often occurs over a large boulder or rubble bottom in inland lakes at depths of less than 40 feet (12.2 m) and sometimes as shallow as 1 foot, but in the Great Lakes at depths less than 120 feet (36.6 m). In rare instances, spawning may occur in rivers, as observed and documented for Montreal and Dog rivers, Lake Superior, by Loftus (1958). Temperatures at time of spawning have been reported at 48° F (8.9° C) (Saskatchewan) to 51°–57° F (10.6°–13.9° C) but spawning is not initiated by temperature alone; some observers suggest light may be influential. The spawning act takes place after dark, for the trout move onto the spawning grounds at about 1900 hours and most depart by 2200.

Cleaning of the spawning grounds, noted by Martin (1957), consisted of brushing the rocks with body or tail fin, or rubbing them with the snout.

One or two males may spawn with one female, or a group of males and females may spawn together, extruding eggs and sperm over rocky bottom. The fertilized eggs fall into the crevices between the large rocks. The eggs are large, measuring 5–6 mm (in ovary) at maturity. The number of eggs deposited depends on the size of the female but ranges from 400–1200 eggs per pound of female. A 32-inch (813-mm) female from the Great Lakes may deposit up to 18,000 eggs.

There is evidence of homing, i.e., returning to the same spawning beds year after year, in some lakes (Martin 1960) but an absence of homing tendencies in others (McCrimmon 1958); even where homing tendencies exist, lake trout will utilize artificial spawning grounds (Martin 1960).

After spawning, lake trout disperse through the lake and may move over 100 miles away. The movements of trout have been studied by marking (tags or fin clipping) and much information has been gathered. They sometimes tend to wander many miles and move freely throughout small and medium-sized lakes.

The eggs remain in their rocky incubator for many weeks. Martin (1957) determined incubation periods for a number of Algonquin Park lakes and observed that, although spawning occurred October 15–30 (except in one case), hatching varied from February 15 to March 30. The period of incubation in that area varied from 15–21 weeks, and temperatures of 32.5°–33.8° F (0.3°–1.0° C) were recorded. Usually 4 to 5 months are required for incubation and hatching usually occurs in March or April, but in Great Bear Lake it is delayed until June. The young usually seek deeper water within a month or so of hatching and after the yolk sac is absorbed, but in far northern lakes they may remain in inshore waters for months or even years, as in Great Bear Lake. In the main, however, the biology of young lake trout is not well known.

The growth rate varies greatly over the whole range but in the central portion of the Canadian range, growth is fairly rapid. Aging has been done most commonly by scale examination but is difficult for ages over about 8 years. Otoliths can also be used and recently the use of the outer branchiostegal ray was recommended as a supplementary method of aging (Bulkley 1960).

Sexual maturity is usually attained about age 6 or 7, but not until age 13 in Great Bear Lake. Comparative rates of growth are shown for a number of lakes, in the table, p. 224.

Lake trout grow to weights in excess of 50 pounds in many Canadian lakes and, on one occasion at least, exceeded 100 pounds. The largest known lake trout in North America was caught in a gillnet in Lake Athabasca, Sask., on August 8, 1961, by Orton Flett. It weighed 102 pounds (46.3 kg) and was 49.5 inches (126 cm), total length. It was a relatively young fish, 20–25 years old. The rapid growth rate was probably related to the fact that it never became sexually mature, according to Dr Helen Battle, University of Western Ontario, who examined the gonads. The specimen is preserved in the ROM collection. Other specimens in excess of 80 pounds were caught in Lake Athabasca about 1961. The angling record for North America is 63 pounds 2 ounces (28.6 kg), for a trout caught in Lake Superior in 1952. In most inland lakes the average size caught by anglers is less than 10 pounds.

The lake trout occurs only in relatively deep lakes through the southern part of its Canadian range, but in the northern half, especially in the Territories, it occurs also in shallow lakes and in rivers. It is the least tolerant of salt water of all the chars, although it has been reported from coastal waters by Weed (1934), Dunbar and Hildebrand (1952), and Walters (1953, 1955). Its saltwater occurrences were reviewed by Boulva and Simard (1968) who concluded that the upper limit of salinity tolerance was between 11–13‰, but it did not enter oceanic salt water having a salinity of 35‰.

In inland lakes in southern Canada the

		Age (years)																							
	FL	0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+	18+	19+	20+	21+	22+	23+	>23+
Lac Mistassini, Que. (Dubois and Lagueux 1968)	*inches*	–	–	–	8.1	9.1	12.4	14.3	16.2	16.9	19.0	19.3	20.1	21.3	20.8	20.8	20.8	21.4	20.5	22.4	22.7	20.5	23.6	23.2	24.3	–
	mm	–	–	–	205	231	315	362	412	428	483	491	511	542	528	528	528	543	521	568	576	520	599	588	618	–
																										–
L. Opeongo, Ont. (Martin 1970)	*inches*	–	–	7.7	9.5	11.0	13.1	14.4	17.4	19.4	21.3	22.8	24.3	25.4	27.8	28.7	29.4	–	–	–	–	–	–	–	–	–
	mm	–	–	196	241	279	333	366	442	493	541	579	617	645	706	729	747	–	–	–	–	–	–	–	–	–
	Wt (*lb*)	–	–	–	–	–	0.8	1.0	1.8	2.6	3.4	4.2	5.1	5.9	7.8	8.6	9.3	–	–	–	–	–	–	–	–	–
Louisa L., Ont. (Martin 1952)	*inches*	–	4.1	6.9	7.7	9.6	12.8	13.5	14.4	15.8	17.3	20.5	20.0	21.8	–	–	–	–	–	–	–	–	–	–	–	–
	mm	–	104	175	196	244	325	343	366	401	439	521	508	554	–	–	–	–	–	–	–	–	–	–	–	–
Lac la Ronge, Sask. (Rawson 1961)	*inches*	–	–	10.5	14.8	16.8	20.1	21.4	23.2	24.1	25.3	26.0	27.2	27.9	29.7	31.0	32.0	32.8	35.0	36.2	–	–	–	–	–	–
	mm	–	–	267	376	427	511	544	589	612	643	660	691	709	754	787	813	833	889	919	–	–	–	–	–	–
	Wt (*lb*)	–	–	–	–	–	3.5	–	–	6.3	–	8.2	–	10.4	–	14.9	16.8	–	22.5	–	–	–	–	–	–	–
Great Slave L., N.W.T. (Kennedy 1954b)	*inches*	5.6	7.0	9.9	11.7	13.6	15.4	17.2	18.9	19.2	21.2	22.9	24.8	26.7	28.6	30.2	31.6	33.1	34.2	35.2	35.9	36.5	37.1	37.6	38.1	–
	mm	142	178	251	297	345	391	437	480	488	538	582	630	678	726	767	803	841	869	894	912	927	942	955	968	–
	Wt (*lb*)	.05	0.1	0.3	0.5	0.8	1.2	1.7	2.3	3.1	4.2	5.3	6.7	8.4	10.3	12.2	14.0	16.0	17.8	19.3	20.6	21.6	22.6	23.6	24.5	–
	TTL																									
Great Bear L., N.W.T. (Miller and Kennedy 1948a)	*inches*	1.1	2.5	3.9	5.3	7.1	–	–	11.5	12.6	13.9	14.7	'6.2	16.2	16.6	17.7	19.2	20.3	21.9	22.6	23.9	24.7	25.8	27.6	27.5	28.3-38.0
	mm	28	63	98	134	180	–	–	293	320	354	372	412	412	420	449	487	515	556	574	607	626	656	700	698	719-965
	Wt (*lb*)	–	.01	.03	.06	–	–	–	.88	.88	1.1	1.3	1.6	1.7	1.8	2.2	3.0	3.6	4.3	5.1	5.8	6.3	6.4	7.9	8.4	8.8-34.0

depth–distribution of lake trout varies with the seasons. In autumn, usually early October, they move into rocky shallows in preparation for spawning. After spawning is completed they disperse freely throughout the lake at various depths and remain dispersed throughout the winter months. In spring they often occur in surface waters immediately after breakup of ice. As surface waters warm with the advance of spring, lake trout retire to the cooler waters, eventually retreating to the hypolimnion, below the thermocline during the warmer summer months. The depth of the thermocline in a particular lake depends on many factors such as latitude, size of lake, height of surrounding land and, hence, protection from wind, but in most small lakes it occurs at depths of 40–60 feet (12.2–18.3 m). Lake trout do make excursions above the thermocline despite the unfavourably warm temperatures. In general, they prefer temperatures of about 50° F (10° C).

In large lakes, they tend to inhabit deeper water. In Lake Superior, Dryer (1966) noted they were most common at all seasons at depths of 60–175 feet (18.3–53.0 m) although there was evidence of seasonal movement.

Lake trout are predaceous and feed upon a broad range of organisms including freshwater sponges, crustaceans, aquatic and even terrestrial insects, many species of fishes (including lake trout), and even small mammals. Food consumed varies with the season, particularly in small inland lakes. In Lake Louisa, Algonquin Park, Ont., Martin (1954) demonstrated that they ate largely plankton in summer because the only forage fish (minnows) were in shallow water and unavailable to them, restrained as they were in cooler, deeper waters by a thermal barrier. But, trout that feed on plankton are slower growing, smaller, and do not live as long as those that feed mainly on fishes (Martin 1966). Invertebrates, particularly *Mysis relicta* and *Pontoporeia*, are important, especially in the diet of young trout.

Ciscoes (subgenus *Leucichthys* spp.) appear to be the preferred natural food of adults of most populations (Rawson 1959, 1961; Dryer et al. 1965; Martin 1970; MacCrimmon and Skobe 1970). Other fishes eaten include whitefish, smelt, perch, sculpins, emerald shiners, ninespine sticklebacks, troutperch, and longnose suckers, to name a few of the many species observed in stomachs.

Although ciscoes appear most commonly in the diet of large trout, other fish species may dominate in certain lakes. In Lake Ontario, the alewife was of primary importance to adult trout (Dymond 1928b) and in Lake Superior the introduced smelt became the most important food fish in 1963, although whitefishes (*Coregonus* spp.) remained seasonally important during October–December (Dryer et al. 1965).

Organisms eaten depend, to some degree, upon availability, and lake trout seem able to take advantage of an abundance of almost any food. In northern Quebec, near Knob Lake, Bleakney (1954) found trout stomachs distended with mosquito larvae and pupae, but the trout were considered to be in poor condition. In the Ungava Bay region of northern Quebec, ". . . mice and shrews are quite often found in the stomach of the lake trout, . . ." (Dunbar and Hildebrand 1952), and similar observations on food in Ungava were reported by Harper (1961). In Lake Opeongo, Martin (1970) noted that the freshwater sponge (*Spongilla*) was commonly found in trout stomachs.

The role of sculpins as food of lake trout warrants special mention. In Lake Michigan, cottids (*Myoxocephalus quadricornis, Cottus ricei, C. cognatus*) were a significant item of diet, and the most important fish component in the diet of trout under 15 inches (381 mm) long (Van Oosten and Deason 1938). In Lake Ontario, although only large lake trout were examined, cottids (especially *M. quadricornis*) were a significant item of food (Dymond 1928b). In Lac la Ronge, Rawson (1961) noted that "The deepwater sculpin is apparently one of the first fish of suitable size and in suitable location to provide food for young trout." Although the lake trout apparently disappeared entirely from Lake Michigan, probably in large measure because of sea lamprey predation, its disappearance from Lake Ontario is more puzzling, for sea lamprey and lake trout had cohabited Lake Ontario for centuries, as they had in Seneca and Cayuga lakes in New York. Perhaps it is significant that the once dense populations of deepwater sculpins have disappeared from Lake Ontario and that none have been seen since 1959–1960.

The lake trout has relatively few enemies under natural conditions, but those in the upper Great Lakes were apparently unable to survive predation by sea lampreys which gained access to the upper lakes by the man-made Welland Canal (*see* under sea lamprey for history and details).

Lake trout eggs are susceptible to predation. Eggs of river-spawning populations in Lake Superior were consumed by round whitefish, according to Loftus (1958), who observed as many as 150 eggs in a single round whitefish stomach. The brown bullhead is another serious predator on lake trout eggs, especially in inland lakes of southern Ontario. In Manitoba, burbot under 3 pounds (1361 g) were reported to eat lake trout eggs (Anon. 1960). Although burbot and lake trout are known to compete for the same food items, extensive studies in Lake Michigan before the disappearance of both species gave no evidence that they fed on each other (Van Oosten and Deason 1938). Occasionally, lake trout become cannibalistic, and will eat smaller lake trout (Martin 1970) and even their own eggs.

Parasites of lake trout in Algonquin Park lakes in Ontario were studied by MacLulich (1943a), who described a new species of tapeworm, *Proteocephalus parallacticus*, which occurred in the intestines of most trout. Hundreds of lake trout from 34 lakes in Algonquin Park were also examined by MacLulich (1943b) who noted 13 species of parasites. The large tapeworm *Eubothrium salvelini* occurred in 85% of lake trout examined. A species of *Diphyllobothrium* occurred frequently in lake trout of some lakes, encysted in the viscera, not in the flesh as is *D. latum*. Transmission of the cestode *Diphyllobothrium* sp. to lake trout in Algonquin Park was studied by Freeman and Thompson (1969) who demonstrated that infection was not always a result of heavy plankton consumption, as previously thought. Rather, they suggested ". . . a suitable species of first fish host probably accounts for much of the higher levels of infection in lake trout in some lakes, although direct transmission from copepods to lake trout may account for the more sparse infections in other lakes."

In addition to the above, Bangham and Venard (1946) also studied parasitism in Algonquin Park lakes, and Bangham and Adams (1954) examined specimens from the Fraser River drainage of British Columbia. Four species of parasites were reported from Lake Huron lake trout by Bangham (1955).

From Wollaston Lake in northern Saskatchewan, Rawson (1959) reported *Eubothrium salvelini*, *Echinorhynchus salvelini*, *Glaridacris catostomi*, and *Schistocephalus solidus* in lake trout. The nematode *Cystidicola stigmatura* was reported by Rawson (1961) from northern Saskatchewan.

From Great Bear Lake, N.W.T., Miller and Kennedy (1948a) reported a similar list of parasites plus *Triaenophorus crassus*, *Diphyllobothrium latum*, *Echinorhynchus coregoni*, *Salmincola siscowet* and leech, *Piscicola milneri*.

Triaenophorus crassus has been found encysted in the flesh of lake trout from many parts of northern Canada including northern Saskatchewan and the Northwest Territories, but infection rates are usually low. *See* under lake whitefish for additional information on *T. crassus*.

Relation to man The lake trout is highly prized both as a game fish and as a commercial species. In some lakes (Lac la Ronge, Sask., Rawson 1961) lake trout are harvested by both commercial and sport fishermen, but where conflicts arise, the resource usually benefits more people when harvested by anglers.

As a game fish in southern Canada, it is caught by fly or spin fishing early in the spring, immediately after breakup of the ice, or by deep trolling with a metal line later in the summer. In the far northern lakes, including those in the Northwest Territories, lake trout remain in surface waters throughout the summer and deep trolling is unnecessary. It is also the object of intense winter fishing through the ice in many parts of Canada. This winter harvest may require greater management control, particularly for lakes that are heavily fished in summer as well as in winter.

Commercially, the lake trout is caught by gillnets. It is a valuable species but the yield has been greatly reduced.

In northern Canada, especially in the Northwest Territories, lake trout fisheries have become increasingly important, supplying the demand of eastern markets that were formerly dependent on Great Lakes stocks. The total Canadian commercial yield of lake trout has declined however, as shown by the take for the years 1964–1968 inclusive:

Year	1964	1965	1966	1967	1968
Thousands of pounds	3384	3176	2984	2941	2390

The famous commercial lake trout fisheries of the Great Lakes have been decimated by the sea lamprey and by pollution, particularly DDT. The latter accumulates in fatty tissues, especially in the yolk of the egg and induces the death of the embryo following yolk absorption. Natural reproduction by lake trout is seriously affected in areas of high DDT concentration (Burdick et al. 1964; Johnson 1968).

Management practice has included the use of hatcheries for artificial propagation. Lake trout are caught in poundnets on the spawning grounds, the eggs and milt stripped and the adults released. The fertilized eggs are reared in hatcheries to the fingerling or even yearling stage, and released. The planting of hatchery stock has been shown to be effective in the Great Lakes. In Cayuga Lake, N.Y., hatchery stock has been vital in the maintenance of the fishery for at least 50 years (Webster et al. 1959).

The lake trout is an esteemed food fish. The flesh may be white, pink, orange or orange-red, the colour being influenced in part, at least, by diet; large piscivorous trout often have white flesh. Irrespective of colour, the flavour is usually excellent. It is most often eaten fresh, but is sometimes smoked and a small amount is canned. The fat lake trout (siscowets) from the deep waters of Lake Superior were edible only when smoked.

Nomenclature

Salmo Namaycush	— Walbaum 1792: 68 (type locality Hudson Bay)
Salmo pallidus	— Rafinesque 1817b: 120
Salmo amethystus (frequently misspelled *amethystinus*)	— Mitchill 1818b: 410
Salmo namaycush (Pennant)	— Richardson 1836: 173
Salmo confinis	— DeKay 1842: 238
	— Adams 1873: 237
Salmo ferox	— Perley 1852: 196
Cristivomer namaycush	— Gill and Jordan *in* Jordan 1878c: 356
Salvelinus namaycush	— Jordan and Gilbert 1883a: 317
	— Miller 1950b: 3

(*See* La Rivers 1962, for additional details of nomenclature)

Etymology *Salvelinus* — an old name for char; *namaycush* — an Indian name.

Common names Lake trout, Great Lakes trout, mackinaw trout, salmon trout, laker, namaycush, masamacush, togue, grey trout, Great grey trout, Great Lakes char, landlocked salmon, mountain trout, taque. French common name: *touladi.*

Suggested Reading – subfamily Salmoninae

Andrews, C. W., and E. Lear, 1956. The biology of Arctic char (*Salvelinus alpinus* L.) in northern Labrador. J. Fish. Res. Bd. Canada 13: 843–860.

Anon. (no date). Salmon. The living resource. Dep. Fish. Can. 23 p.

Ayers, H. D., H. R. McCrimmon, and A. H. Berst. 1963. Construction and management of farm ponds in Ontario. Ont. Dept. Agr. Publ. 515: 39 p.

Bridges, C. H., and J. W. Mullan [ed.]. 1958. A compendium of the life history and ecology of the eastern brook trout *Salvelinus fontinalis* (Mitchill). Mass. Div. Fish Game, Fish. Sect. Fish. Bull. 23: 30 p.

Brown, M. E. 1957. The physiology of fishes. Vol. 1. Metabolism. Academic Press Inc., New York, N.Y. 447 p.

Brynildson, O. M., V. A. Haker, and T. A. Klick. 1963. Brown trout. Its life history, ecology and management. Wis. Conserv. Dep. Publ. 234: 14 p.

Chambers, E. T. D. 1896. The ouananiche and its Canadian environment. Harper & Brothers, New York, N.Y. 357 p.

1912. The fisheries of the Province of Quebec. Part 1. Dep. Colon. Mines Fish. Que. 206 p.

Cope, O. B. 1964. Revised bibliography on the cutthroat trout. U.S. Fish Wildl. Serv. Bur. Sport Fish. Wildl. Res. Rep. 65: 43 p.

Dymond, J. R. 1963. Family Salmonidae, p. 457–502. *In* Fishes of the western north Atlantic. Mem. Sears Found. Mar. Res. 1(3): 630 p.

Eipper, A. W. 1964. Growth, mortality rates, and standing crops of trout in New York farm ponds. Cornell Exp. Sta. Mem. 388: 67 p.

Gillespie, G. J. 1968. The Atlantic salmon. Can. Geogr. J. 76(6): 186–200.

Grainger, E. H. 1953. On the age, growth, migration, reproductive potential and feeding habits of the Arctic char (*Salvelinus alpinus*) of Frobisher Bay, Baffin Island. J. Fish. Res. Bd. Canada 10: 326–370.

Haig-Brown, R. L. 1967. Canada's Pacific salmon. Dep. Fish. Can. 29 p.

Havey, K. A., and K. Warner. 1970. The landlocked salmon (*Salmo salar*). Its life history and management in Maine. Sport Fish. Inst. Washington, and Me. Dep. Inland Fish. Game. 129 p.

Hoar, W. S. 1951. The chum and pink salmon fisheries of British Columbia, 1917–1947. Fish. Res. Board Can. Bull. 90: 46 p.

1958. The evolution of migratory behaviour among juvenile salmon of the genus *Oncorhynchus*. J. Fish. Res. Bd. Canada 15: 391–428.

Jones, J. W. 1959. The salmon. Collins, London. 192 p.

MacCrimmon, H. R. 1971. World distribution of rainbow trout (*Salmo gairdneri*). J. Fish. Res. Bd. Canada 28: 663–704.

MacEachern, N. E. J., and J. R. MacDonald. 1962. The salmon fishery in Nova Scotia. Can. Fish. Cult. 31: 43–57.

McPhail, J. D. 1961. A systematic study of the *Salvelinus alpinus* complex in North America. J. Fish. Res. Bd. Canada 18: 793–814.

McPhail, J. D., and C. C. Lindsey. 1970. Freshwater fishes of northwestern Canada and Alaska. Fish. Res. Board Can. Bull. 173: 381 p.

Narver, D. W. 1969. Age and size of steelhead trout in Babine River, British Columbia. J. Fish. Res. Bd. Canada 26: 2754–2760.

Netboy, A. 1968. The Atlantic salmon. A vanishing species? Faber and Faber, London. 457 p.

Norden, C. R. 1961. Comparative osteology of representative salmonid fishes, with particular reference to the grayling (*Thymallus arcticus*) and its phylogeny. J. Fish. Res. Bd. Canada 18: 679–791.

Northcote, T. G. [ed.] 1969. Symposium on salmon and trout in streams. H. R. MacMillan lectures in fisheries. Univ. British Columbia, Vancouver, B.C. 388 p.

Power, G. 1969. The salmon of Ungava Bay. Arctic Inst. Amer. Tech. Pap. 22: 72 p.

Scott, W. B., and E. J. Crossman. 1964. Fishes occurring in the fresh waters of insular Newfoundland. Dep. Fish., Ottawa. 124 p.

Séguin, L.-R. 1955. Moeurs et méthodes d'élevage des truites du Québec. Jeune Natur. 5(7): 146–176.

Séguin, R. L. 1956. Limites géographiques et facteurs climatiques de la distribution naturelle de la truite mouchetée. Rev. Can. Geogr. 10: 113–117.

1957. Management, fishing results and growth of speckled trout (*Salvelinus fontinalis*) in Baldwin Pond, Stanstead County, Que. Can. Fish. Cult. 20: 29–37.

Tsuyuki, H., and E. Roberts. 1966. Inter-species relationships within the genus *Oncorhynchus* based on biochemical systematics. J. Fish. Res. Bd. Canada 23: 101–107.

Various Authors. 1947–1957. Pacific salmon. Selected articles from Soviet periodicals. 284 p. (Transl. from Russian by Israel Program for Sci. Transl., Jerusalem). (Available from Office Tech. Serv. U.S. Dep. Comm., Washington.)

Vladykov, V. D. (no date). Atlantic salmon. Fishes of Quebec. Que. Dep. Fish. Album 2: 6 p.

1963. A review of salmonid genera and their broad geographical distribution. Trans. Roy. Soc. Can. 4(1): 459–504.

Wilimovsky, N. J. [ed.] 1962. Symposium on pink salmon. H. R. MacMillan lectures in fisheries. Inst. Fish. Univ. British Columbia, Vancouver, B.C. 226 p.

SUBFAMILY COREGONINAE Whitefishes, round whitefishes, ciscoes, with an orbitosphenoid, dermosphenotic, and hypethmoid; without suprapreopercle or epipleurals; maxilla without teeth; parietals meet at midline; 15 or fewer dorsal fin rays; eggs small, a postlarval stage, young usually without parr marks (but present in *Prosopium*).

Some authors accord family rank to the whitefishes and refer to the group as the Coregonidae, but we have chosen to consider them as a subfamily of the family Salmonidae, as suggested by Norden (1961a).

This group of fishes is the most widely distributed and, taxonomically, the most perplexing of all Canadian freshwater fishes. In this work, we recognize 18 species, in 3 genera, as follows: *Stenodus* (1 species), *Prosopium* (3 species), and *Coregonus* (14 species). It is within the genus *Coregonus* that the most difficult taxonomic problems arise, particularly with those whitefishes in which the upper and lower jaws are more or less equal and which have more than 32 gill rakers. These whitefishes, with terminal mouths and high gill raker counts, are called ciscoes or lake herrings. Until about 1960, these fishes were grouped in the genus *Leucichthys*, but studies by Norden (1961a) indicated that they more properly belonged in the genus *Coregonus* (subgenus *Leucichthys*). Few ichthyologists would agree on the exact number of species of ciscoes in Canadian waters, because they are so exceedingly difficult to identify. Some recent authors (McPhail and Lindsey 1970) referred to one of the most variable species (or species groups), *Coregonus artedii*, as "*C. artedii*" complex, in recognition of the difficulty of affixing a precise name to its members.

The difficulties in identification are directly related to the variability of whitefishes from lake to lake, variability in such features as shape, size, growth rate, and numbers of scales and gill rakers, characters that are directly influenced by the environment. Thus, the basic plan of each species (its genotype) is modified by the environmental conditions existing in each body of water. To identify ciscoes in the Great Lakes, it is wise to consider the variation of related species in the same lake, for characters that clearly distinguish two species in one lake may not be reliable in another. (*See* Scott and Smith 1962; Smith 1964a.)

While some species of ciscoes are wide ranging, like *C. artedii*, others are restricted in distribution. For example, within the Great Lakes basin there are five species of ciscoes that, as far as we know, are restricted to the Great Lakes basin and apparently do not occur anywhere else. These endemic ciscoes live (or did live, until recent years) in the deeper waters of the Great Lakes. The five species are listed below, more or less in order of size:

deepwater cisco, *Coregonus johannae*
longjaw cisco, *Coregonus alpenae*
shortnose cisco, *Coregonus reighardi*
kiyi, *Coregonus kiyi*
bloater, *Coregonus hoyi*

All five occurred only in lakes Huron and Michigan, four occurred in Lake Superior, three in Lake Ontario, two in Lake Nipigon, and one in Lake Erie.

Canadians have taken little interest in these Great Lakes endemic species, either commercially or biologically. No serious studies of any of them have been conducted in Canada since the period of intense activity stimulated in the University of Toronto during the 1920's and 1930's when Bensley, Dymond, and their students and colleagues, investigated the fishes of lakes Ontario, Erie, and Nipigon. Thus, with few exceptions, data resulting from Canadian studies on Great Lakes endemic ciscoes are 30 years old or more. In fact, few morphometric or meristic data have been published by anyone in the last 20 years, for attention has been directed more and more toward changes in the ecology of the Great Lakes and, in particular, changes in population levels of the different species.

In addition to the endemic deepwater ciscoes, there were two other species of ciscoes that lived in deep water, the blackfin cisco, *C. nigripinnis*, and the shortjaw cisco, *C. zenithicus*. These two species, together with the five endemic ciscoes, were collectively known as "chubs." Thus, "chubs" were ciscoes of the genus *Coregonus* (subgenus *Leucichthys*), exclusive of *Coregonus artedii*, but comprising seven species (in descending order of size: *nigripinnis, johannae, zenithicus, alpenae, reighardi, kiyi, hoyi*). These were seldom identified to species but were simply marketed as "chubs," and reached the consumer almost exclusively as smoked fish. The principal market, indeed the principal fishery, was in the United States where the product was considered a delicacy. It was seldom sold in Canada.

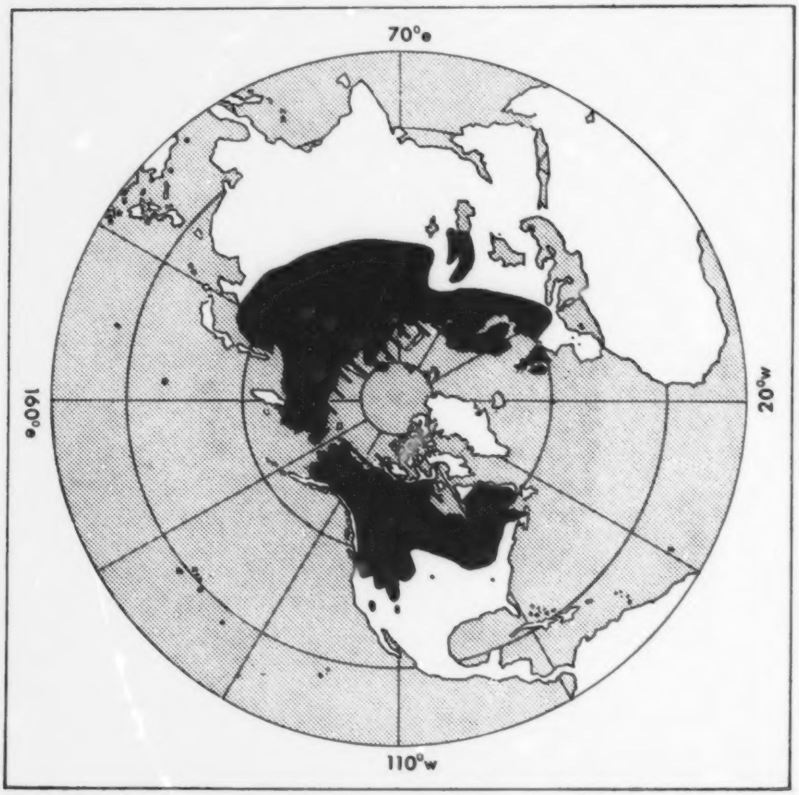
Until about 1950, the Great Lakes supported a substantial chub fishery. Chubs were caught exclusively by gillnets set in deep water. The larger, fatter chubs were preferred, especially the species *nigripinnis*, *johannae*, and *alpenae*, but as these became scarce, *zenithicus* and *reighardi* were caught in increasing numbers and finally the smaller species, *kiyi* and *hoyi*, which were originally spurned, entered the fishery. The chub fishery, as such, ceased to exist before 1960, and today, the bloater, *C. hoyi*, is really the only species supplying this traditional smoked fish market.

The history of the whitefish and cisco fisheries of the Great Lakes is one of increasing exploitation and dwindling stocks. As the catches decreased, the amount of gear fished increased, so that a review of the annual poundage caught does not indicate the decline in catch per unit effort. In a repetitive fashion, each fishery declined and finally collapsed, and although many explanations for the declines have been given, of which predation by the sea lamprey is the most common, some fisheries, at least, declined and vanished without apparent relation to sea lampreys. The Lake Erie cisco and whitefish fisheries are good examples. It was naive to expect that any population of organisms could withstand such continuous and intense exploitation at the same time that the habitat was being destroyed by such activities as gravel removal, gas well drilling, and sewage discharge.

Much of our knowledge of the ecology of the Great Lakes ciscoes was gathered before the drastic changes occurred in the species composition of the Great Lakes — changes wrought in large measure by intense commercial fishing, by reduction in the populations of lake trout and burbot because of sea lamprey predation, but aided and intensified by environmental degradation.

As a result of breakdown in the established ecological structure, the populations of the endemic species, particularly the larger ones, have been drastically affected and many species no longer occur in lakes where they once supported substantial fisheries. (*See* papers by Moffet 1957; Smith 1964a, 1968.) For example, *C. nigripinnis*, *C. reighardi*, and *C. kiyi* have not been seen in Lake Ontario for many years. *C. johannae* and *C. alpenae* have presumably disappeared from Lake Huron. All five endemic species, except *C. hoyi*, have apparently disappeared from Lake Michigan.

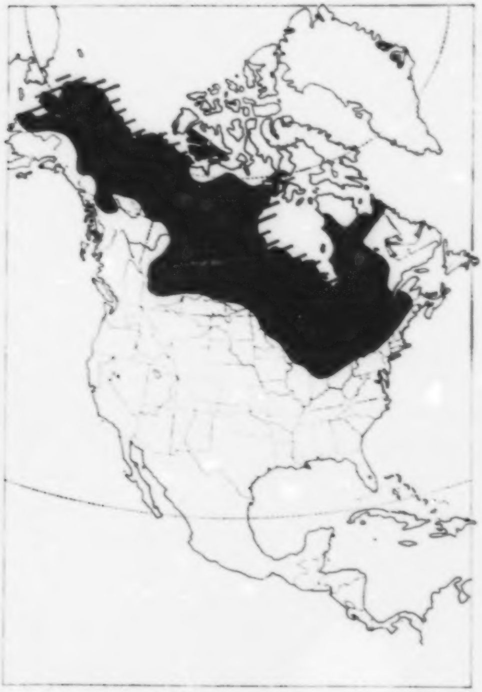
Associated with the disappearance of familiar species is the appearance of ciscoes in deep water which differ morphometrically from those that previously lived there. The deepwater ciscoes have been difficult to identify in the past, but in recent years have become even more so. This phenomenon was thoroughly discussed by Smith (1968), who noted that many of the "new" ciscoes resembled *hoyi* but were more robust than that species used to be. Other "new" ciscoes resembled *C. artedii* but were also more robust and tended to be deeper bodied. Smith noted also that differences in morphological measurements and counts were irregular and that the new forms exhibited complete gradation into the typical appearance of the species they resembled. Some biologists believe that introgressive hybridization (that is, interbreeding and back crossing) has been taking place and species that become rare, in the absence of mates of their own kind, have been hybridizing with the more common *hoyi* and *artedii*. In any case, ciscoes in the Great Lakes seem to have changed considerably since the publication of the *Coregonid Fishes of the Great Lakes* by Walter Koelz (1929), and whitefishes in inland waters continue to confound us and to defy ready taxonomic placement. Hence, the following descriptions for all members of the genus *Coregonus*, but especially the ciscoes or lake herrings (subgenus *Leucichthys*), are general, except where noted otherwise, and cannot be regarded as rigid delimitations of the species throughout its range. Additional descriptive references are given whenever possible.



World Distribution of the Whitefishes

COMPARATIVE TABLE FOR GREAT LAKES CISCOES

	Lake	Depth range (*fath*)	Month(s) of spawning	Gill raker range	Avg length (*mm*)
alpenae —	Erie (rare)	3–34	November	30–39	245
	Huron	14–100	November	31–44	380
	Michigan	5–90	November	33–46	380
artedii —	Ontario	0–75	November – early December	41–54	250
	Erie	0–32	November–early December	38–53	375
	Huron	0–35	November–early December	40–53	300
	Superior	0–90	November–early December	38–53	250
	Over whole range	0–90	September–December	38–64	375
hoyi —	Ontario	16–75	between November and March (but uncertain)	39–50	>200
	Huron	0–100	February (uncertain)	37–47	<200
	Michigan	0–90	March	37–48	>200
	Superior	15–90	after December (but uncertain)	37–49	<200
	Nipigon	15–54	unknown	40–48	<200
johannae —	Huron	15–100+	late August–September	25–35	300
	Michigan	30–90	mid-August–end Sept.	26–36	300
kiyi —	Ontario	20–75	August	41–48	230
	Huron	60+	October–November (uncertain)	36–44	<200
	Michigan	30–90	October	34–45	230
	Superior	40+	late November–early December	36–45	<200
nigripinnis —	Ontario	max 60 1 spec.	(January)	–	–
	Huron	35–100+	late November–Dec.	40–52	250–350
	Michigan	30+	late December–early Jan.	41–52	250–350
	Superior	15–100+	September–early October	36–48	250–350
reighardi —	Ontario	20–75	early May	33–42	240–295
	Huron	–	–	–	information not available
	Michigan	6–90	May, early June	30–43	<240
	Superior	0–65	October–early November	32–42	250
	Nipigon	10–30+	November	32–38	<240
zenithicus —	Huron	14–100	mid-September, October	34–44	<300
	Michigan	12–90	October, November	35–44	<300
	Superior	11–100	late November, early December	32–46	<300
	Nipigon	6–54	late October, early November	33–42	<300



North American Distribution of Ciscoes,
Subgenus Leucichthys

LONGJAW CISCO

Coregonus alpenae (Koelz)

Description Body elongate, average total length about 10.5 inches (267 mm), compressed laterally but robust, greatest body depth in front of dorsal fin, 23–27% of total length. Head heavy, broad and short, 20–25% of total length; eye moderate, its diameter smaller than snout; snout broad, somewhat rounded; mouth terminal, lower jaw heavy, usually projecting beyond upper jaw, maxillary usually not pigmented, extending posteriorly to beyond the anterior margin of eye. Gill rakers 30–39 (Lake Erie), 33–42 (Lake Huron) and 31–44 (Lake Huron), 33–46 (Lake Michigan). Branchiostegal rays 8–10 (Lake Huron). Fins (all fin ray counts from Lake Erie): small dorsal adipose present; dorsal 1, rays 10–13; caudal distinctly forked; anal rays 10–14; pelvic rays 10–13; pectoral rays 13–16. Scales cycloid, large 68–83 in lateral line. Vertebrae 56–59.

Nuptial tubercles developed on breeding males.

(*See* Koelz 1924, 1929; Scott and Smith 1962.)

Colour Overall colouration silvery with pink or purple iridescence, green or blue on back, silvery on sides and white below. Pigmentation on jaws and fins very light.

Systematic notes This endemic deepwater cisco was described by Koelz (1924). The holotype is a female (immature), 10.6 inches (269 mm) in standard length, caught in Lake Michigan, June 15, 1923, at a depth of 150–282 feet (45.7–86.0 m). It is in the United States National Museum, cat. no. 87352, and was in good condition when examined in 1959.

Distribution The longjaw cisco is indigenous to the Great Lakes basin and occurred only in lakes Huron and Michigan. Evidence of a small population in Lake Erie was published recently (Scott and Smith 1962), but it is most unlikely that the species still survived in Lake Erie in 1970. The species was also decimated in Lake Michigan and must be near extinction there.

Biology Spawning apparently took place in November in lakes Michigan and Huron, according to the evidence available, although females with ripe eggs were reported as early as July and spawning as early as October 16 (Jobes 1949a). This early ripening of occasional individuals has been noted for other deepwater ciscoes. Koelz (1929, p. 376, 377) reported on his finding, in late November, 1919, of females with freely flowing spawn, and pearl organs on males of longjaws, taken in Colpoys Bay, Georgian Bay, Lake Huron. It must be noted that the observations on which this report was based were made 5 years before the species was described, although Koelz was undoubtedly familiar with the species. The depth of spawning was not precisely known. Koelz (1929) believed spawning to occur at 60–150 feet (18.3–45.7 m) in Lake Michigan, but it was possibly deeper.

Age analyses, using scales, indicated a relatively rapid rate of growth for the longjaw. Males and females grew at about the same rate and sexual maturity was usually attained at age 3 or 4. Lake Michigan fish attained a weight of about 6.1–6.4 ounces and a length of 11 inches (279 mm) at age 4 and about 12 inches (305 mm) at age 5. In his original description, Koelz (1924) noted that individuals did not usually attain a length of 15 inches (380 mm) or a weight of 2 pounds. Lengths at various ages for lakes Michigan and Erie are shown below:

	Total tip length			
Age	L. Erie, Ont. (Scott and Smith 1962)		L. Michigan (Jobes 1949a)	
	(inches)	*(mm)*	*(inches)*	*(mm)*
1+	5.1	130	–	–
2+	8.6	218	10.9	277
3+	10.6	269	11.5	292
4+	12.7	323	12.0	305
5+	–	–	12.8	325
6+	–	–	14.0	356
7+	–	–	14.8	376
8+	–	–	16.6	421
9+	–	–	17.3	439

In Lake Huron the longjaw cisco was considered to live at depths of 300–360 feet (94.4–112.7 m) (Koelz 1924, said they were most abundant at depths less than 360 feet) except possibly during spawning, when there was an apparent movement into waters of at least half this depth. There is some minor discrepancy in the available literature concerning preferred depths. Jobes (1949a) found the species most abundant at depths less than 420 feet (128 m) but recorded finding it as deep as 582 feet (177 m). In Lake Erie, most captures were made at depths of about 200 feet (31 m) but it was caught in waters as shallow as 60 feet (18.3 m) (Scott and Smith 1962).

Few food studies have been conducted, but the contents of 30 stomachs of this cisco from Lake Michigan were reported by Koelz (1929). *Mysis relicta* appears to have been the principal food, but occasionally bottom invertebrates such as fingernail clams and aquatic insect larvae were eaten. Koelz's conclusions were recently substantiated by Bersamin (1958) who considered that *Mysis* made up 95% of the food of *alpenae* in Lake Michigan, the remaining 5% consisted of *Pontoporeia*. As many as 458 *Mysis* were counted in a single stomach.

The longjaw formed part of the food supply of the lake trout and burbot populations before these fishes were decimated by the sea lamprey, and it seems likely that the lamprey preyed on longjaw also. It was also the object of intensive commercial fishing.

Bangham (1955) examined one specimen of longjaw cisco from the North Channel of Lake Huron and found it to be infected with the trematode *Diplostomum* sp., and acanthocephalan *Echinorhynchus salmonis*.

Relation to man The longjaw was one of the deepwater ciscoes preferred by the smoked fish trade and, hence, was important in the chub fishery. It is probably extinct or nearly so in Lake Michigan, but its status in Lake Huron is not known. It has not been seen in Lake Erie since 1957. For additional information *see* section on chubs and deepwater ciscoes p. 230–231.

Nomenclature

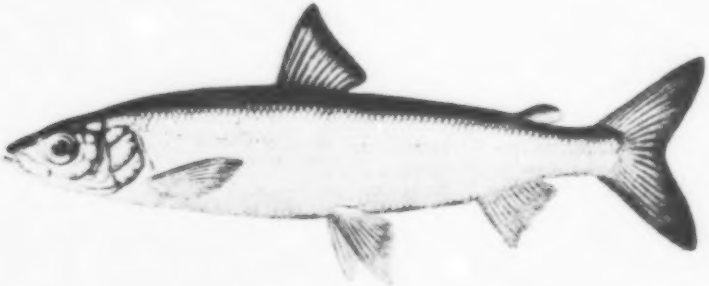
Argyrosomus prognathus	— Evermann and Smith 1896: 314
Leucichthys johannae	— Jordan and Evermann 1911: 24
Leucichthys alpenae	— Koelz 1924: 1–5 (type locality Lake Michigan off Ile aux Galets, 22 miles NE of Charlevoix, Mich.)
Coregonus alpenae (Koelz)	— Hubbs and Lagler 1958: 54
	— Scott and Smith 1962: 1013

Etymology *Coregonus* — angle-eye, coined by Artedi from the Greek words meaning pupil (of the eye), and angle; *alpenae* — probably named after town of Alpena, Mich.

Common names Longjaw cisco, longjaw, longjaw chub. French common name: *cisco à grande bouche*.

CISCO, LAKE HERRING

Coregonus artedii Lesueur



Description Body elongate, total length 8–12 inches (203–305 mm) variable from lake to lake, compressed laterally, greatest body depth in front of dorsal fin, 20–30% of total length (but body depth most variable, females deeper bodied than males). Head length about 20–24% of total length; eye moderate, its diameter 21–26% of head length; snout usually longer than eye; mouth terminal, lower jaw often projecting slightly beyond upper, but jaws may be equal or upper protruding slightly when mouth closed, maxillary extending posteriorly to below anterior half of eye. Gill rakers, range in total count, 38–64, but 41–54 (Lake Ontario), 38–53 (Lake Erie, Lake Superior), 41–57 (Lake Nipigon), 54–64 (*C. nipigon* in Lake Nipigon), 41–50 (Great Bear Lake). Branchiostegal rays 7–9 (Great Lakes), 7–10 (Great Bear Lake). Fins: small dorsal adipose present; dorsal 1, rays 10–15; caudal distinctly forked; anal rays 11–15; pelvic rays 11 or 12, pelvic axillary process present; pectoral rays 14–18. Scales cycloid, large, 63–94 in lateral line (63–81 in Lake Erie). Vertebrae 50–63 (50–60, Lake Erie; 56–63, McPhail and Lindsey 1970).

Nuptial tubercles or pearl organs well developed on scales of breeding males, one appearing on the centre of each scale and on most rows above and below the lateral line.

(*See also* Dymond 1926; Koelz 1929, 1931; Dymond 1943; Scott 1950; Kennedy 1953a; McPhail and Lindsey 1970.)

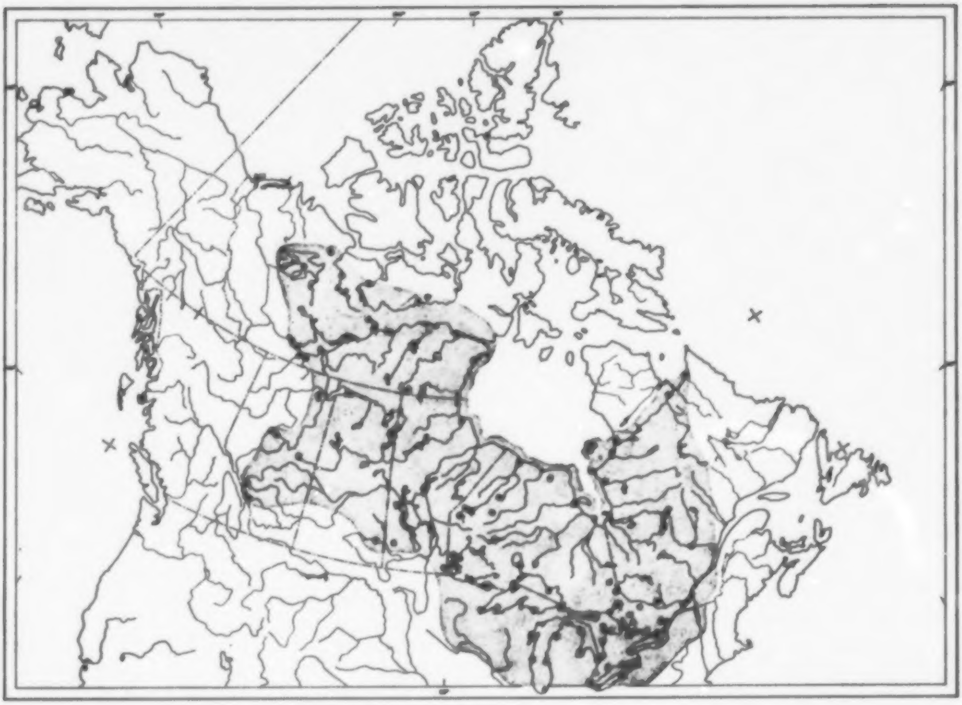
Colour Overall colouration is silvery with pink to purple iridescence. The colour of the back varies greatly from lake to lake (or population to population in large lakes) from almost black to nearly any shade of blue or green to gray or light tan (whence such names as blueback and grayback); silvery on sides and white below. All fins more or less clear but pelvics and anal milky or opaque on adults and usually only lightly sprinkled with black pigment, if at all; remaining fins, especially dorsal and caudal, with varying amounts of dark pigment, sometimes densely concentrated on outer half or on margins.

Systematic notes The lake herring, or cisco, was named by Lesueur (1818a), based on specimens from "Lake Erie and Lewiston upper Canada." The type is not extant but an extensive discussion of Lesueur's description and the type locality (Lake Erie is above Niagara Falls, Lewiston is below, and ciscoes caught there would probably be Lake Ontario stock) was given by Koelz (1929, p. 476–477), who restricted the name *artedi* to the slender form. The species has now been decimated from Lake Erie and still persists, although at low population levels, in Lake Ontario. Fortunately, there are large reference collections from both lakes available in the Royal Ontario Museum and the Museum of Zoology, University of Michigan.

The great variability in morphometry, meristics, and general appearance, in addition to its very extensive range, have led to a large number of synonyms. Twenty-four subspecies were described by Koelz (1931) who used the Lake Michigan form as representative of typical *artedii*, an action that seems regrettable for many reasons. In any case that population, too, is nearly extinct. A few authors continue to recognize subspecies, particularly in the Great Lakes region. Hubbs and Lagler (1964) listed 22 such subspecies, many of which were restricted to only one or two lakes. Such an approach to the taxonomy of this wide-ranging and variable species is totally unrealistic. If this same approach were followed throughout the extensive Canadian range the result would be taxonomic chaos. Within the Great Lakes, the validity of the subspecies is probably now an academic question anyway which will never be satisfactorily answered, for the populations have been altered too drastically and some have become extinct (*see* p. 230–231).

In an attempt to treat the problem from a broad, rather than narrow, approach, McPhail and Lindsey (1970) considered the lake herring to be a species complex and referred to it as "*Coregonus artedii*" complex. In an extensive discussion, they identified the northwestern species included in their complex with which, in the main, we agree. But the evidence for including *C. macrognathus*, *C. entomophagus* and *C. athabascae* in *artedii* rather than *zenithicus* is unconvincing (*see C. zenithicus* p. 265).

In addition to the species included by McPhail and Lindsey in this species group, we include *Coregonus nipigon*, a form described by Koelz (1925) from Lake Nipigon, Ont. Most deep-bodied ciscoes, having high gill raker counts, are assigned to this species because available keys indicate *C. nipigon* if gill rakers add up to 54 or more (Dymond 1947), or 56–59 (Hubbs and Lagler 1964).



To our knowledge *C. nipigon* specimens under 10 inches (254 mm) total length have seldom been seen, their biology is unknown, and spawning populations have never been located. In his original description, Koelz noted that the species resembled the *tullibee* of Richardson from Pine Island Lake but that the inadequate description of that species did not permit him to make a comparison. We considered that Richardson's *tullibee* of Pine Island Lake, Man., (redescribed by Dymond 1928a) also belonged to the wide-ranging *C. artedii*.

Coregonus artedii is a problem species or species group in great need of critical review, the more so because of its commercial importance. Although we have not adopted the terminology *"Coregonus artedii"* complex of McPhail and Lindsey, we are in complete agreement with the thought it conveys.

Distribution This species has the most extensive North American distribution of any cisco, since it is found in the north-central and eastern United States and throughout most of Canada. It occurs from eastern Quebec to Hudson Bay, where it enters coastal salt water and even occurs in ponds on many of the islands, through the Great Lakes system and in innumerable inland lakes through Quebec, Ontario, Manitoba, Saskatchewan, and Alberta, north into the Northwest Territories and, in the Mackenzie River system, north at least to Great Bear Lake. McPhail and Lindsey (1970) noted that it had not been reported from the Peace or Liard River systems.

Biology The biology of this species is better known than that of any other cisco. Many studies have been made in a number of inland lakes as well as in the Great Lakes proper. Two of these are particularly important because they are comprehensive and have been so frequently quoted in subsequent studies — *Life history of the lake herring*

(*Leucichthys artedi Le Sueur*) *of Lake Huron as revealed by its scales, with a critique of the scale method*, by John Van Oosten (1929), and *Morphometry of the cisco, Leucichthys artedi* (*Le Sueur*) *in the lakes of the northeastern highlands, Wisconsin*, by Ralph Hile (1937). The wealth of published data, however, discourages summarization and the interested student should consult the *Suggested Reading* section as well as the literature cited.

Like most coregonines, spawning takes place during times of declining temperatures in the fall of the year, the exact date depending upon water temperature. Large schools or aggregations are formed during spawning. In the Great Lakes and surrounding waters, spawning occurs in late November or early December, but farther north, in the Hudson Bay region, it may take place as early as September (Dymond 1933). The lake herring usually spawns a week or two after the lake whitefish. In small inland lakes, spawning is usually underway when ice begins to form around the shores, making it difficult to study and observe spawning behaviour. In Wisconsin, Cahn (1927) noted that spawning occurred at temperatures around 39.0°–41.0° F (4.0°–5.0° C) but reached its peak at 37.9° F (3.3° C). Spawning will take place, however, even if the temperature does not drop to 39.0°–41.0° F (4.0°–5.0° C). The question of delayed spawning was thoroughly discussed by John (1956).

In inland lakes, spawning usually takes place in shallow water, 3–10 feet (1–3 m) deep over almost any kind of bottom but often over a gravel or stony substrate. In the Great Lakes, spawning may occur in shallow water (Pritchard 1931; Smith 1956) or at much greater depths and even pelagically in midwater 30–40 feet (9–12 m) below the surface, in water 210 feet (64 m) deep (Dryer and Beil 1964). Males always move onto the spawning grounds a few days before the females and may leave before they do, or may remain for a few days after the females have left. Apparently the presence or absence of postspawning males on spawning grounds is dependent upon such factors as the sex ratio of the population, and weather conditions. Stormy weather will drive spawners off the grounds and into deeper water. The date of spawning is primarily temperature dependent and is, therefore, predictable in small inland lakes but may vary in larger lakes where different conditions in various parts of the lake provide optimum spawning conditions at slightly different times.

It is during the fall spawning aggregations that ciscoes are most readily caught and, in unpolluted and unexploited areas, may occur in exceedingly large numbers (*see* section *Relation to man*).

The eggs are deposited on the bottom and abandoned by the parents. The size of the eggs measured on removal from the body cavity of partly spent Lake Erie females in 1947 and 1948 ranged in diameter from 1.8–2.1 mm. Fecundity studies of ciscoes in the Great Lakes region suggest that the number of eggs is positively correlated with size, the larger females producing the greater number of eggs, but there is wide variation. On the average, a 12 inch (305 mm) female from Lake Ontario produced about 22,000 eggs, from Lake Erie about 29,000, and from Lake Superior about 6000. (Stone 1938; Scott 1951; Dryer and Beil 1964).

Development of the eggs proceeds slowly at the low winter temperatures. It is unlikely that hatching occurs under the ice in the southern parts of Canada, although few careful studies have been made; rather, the work of John and Hasler (1956) indicated that hatching did not occur until after the spring breakup of surface ice. For a discussion of factors affecting hatching, *see* John and Hasler (1956), who demonstrated that the young larval ciscoes began to feed before the yolk sac had been absorbed and that at the time of hatching they could survive 20 days of starvation, possibly a few days longer at lower temperatures.

Developmental stages of eggs and larval stages to 17.5 mm long were described and illustrated by Fish (1932) but were described in much greater detail by Pritchard (1930) who worked on Lake Ontario. The survival and development of eggs at various temperatures were studied by Colby and Brooke (1970) who concluded that the optimum incubation temperature under experimental conditions was 42.1° F (5.6° C). At this temperature, 92 days were required for hatching, but 106 days were required at 41.0° F (5.0° C), and 236 days at 32.9° F (0.5° C). Scales first develop above the anal fin, near the lateral line and have been observed on specimens only 34 mm long (Hogman 1970). Scales of Lake Huron ciscoes were critically studied by Van Oosten (1929), who demonstrated the validity of the scale method of age determination clearly and graphically. Few fishes have scales as easy to age or "read" as lake herrings of ages 1–3 years.

Growth characteristics of lake herring from many parts of Canada have received critical study. In general, males and females grow at about the same rate, although females tend to live longer and may reach a larger size. Ciscoes in Great Bear Lake have been reported to reach 13 years of age (i.e. in their 14th year). Maturity is attained at different ages in different populations, sometimes at age 2, usually age 3 or 4, but not

		Age (*years*)										
		1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+
L. Ontario (Pritchard 1931)	FL											
	inches	5.6	8.3	9.7	10.1	10.8	11.5	12.9	13.6	16.3	–	–
	mm	142	211	246	257	274	292	328	345	414	–	–
	Wt (*oz*)	1.1	3.7	5.6	6.4	7.6	10.7	17.2	16.0	26.5	–	–
South Bay, L. Huron, Ont. (Keleher 1953)	SL											
	inches	–	6.2	8.2	8.2	8.4	–	–	–	–	–	–
	mm	–	156	209	208	212	–	–	–	–	–	–
Bay City, L. Huron, Mich. (Van Oosten 1929)	TL											
	inches	–	8.2	9.1	9.4	9.7	10.2	10.8	11.5	–	–	–
	mm	–	208	231	239	245	258	273	292	–	–	–
Green Bay, L. Michigan, Wisc. (Smith 1956)	TL											
	inches	–	8.1	10.4	10.7	11.0	12.9	–	–	–	–	–
	mm	–	206	264	272	279	328	–	–	–	–	–
	Wt (*oz*)	–	2.4	4.4	4.9	5.4	9.3	–	–	–	–	–
Marquette, L. Superior, Mich. (Dryer and Beil 1964)	TL											
	inches	–	12.6	12.7	12.8	12.7	13.6	–	–	–	–	–
	mm	–	320	323	325	323	345	–	–	–	–	–
Lake-of-the-Woods, Minn. (Carlander 1945)	SL											
	inches	4.2	6.3	8.2	9.7	10.8	11.6	12.6	13.2	15.0	15.8	–
	mm	106	161	207	246	275	295	319	336	380	402	–
L. Winnipeg, Man. (Keleher 1950)	SL											
	inches	–	–	8.1	9.1	9.8	10.6	11.5	12.1	12.8	13.9	–
	mm	–	–	206	230	249	270	291	308	325	353	–
L. Winnipeg, Man. (Keleher 1950)	SL											
	inches	–	–	–	9.1	9.9	10.3	10.5	–	–	–	–
	mm	–	–	–	230	252	262	267	–	–	–	–
		(identified as *C. nipigon*)										
Great Bear L., N.W.T. (Kennedy 1949b)	FL											
	inches	–	–	–	10.0	11.2	12.4	12.6	13.1	13.8	14.0	–
	mm	–	–	–	254	284	315	320	333	351	356	–
	Wt (*oz*)	–	–	–	8.0	9.0	13.0	14.0	16.0	18.0	18.0	–

until age 5 or 6 in Great Bear Lake. In inland lakes, weights of 0.5–1.5 pounds are common, in the Great Lakes 3–4-pound fish are uncommon, but this size is not unusual in the Prairie Provinces. The largest lake herring or tullibee recorded from Great Slave Lake weighed 5.5 pounds, was 22.5 inches (572 mm) long, and was caught in 1944. It is in the ROM collection, cat. no. 13498. The largest lake herring known to us was an 8 pound, 7-year-old female caught in central Lake Erie in 1949.

This is essentially a lake species, although it may occur in large rivers in the Hudson Bay region (Dymond 1933) and westward. It is a pelagic species, usually forming large schools in midwaters but its midwater depth varies with the seasons and the temperature. In Lake Superior, Dryer (1966) found it to have an all-season depth range of 60–174 feet (13–53 m). In general, there is a movement in spring and early summer from shallow to deep water, when lake herring move below the thermocline. They remain in the cooler, deep water until late summer, rising to just below the thermocline. As the upper waters cool, they move into shallower water (Fry 1937). The habit of moving into deeper water during summer may lead to mass mortalities if the hypolimnion becomes depleted of oxygen (McCrimmon 1952). The temperature tolerance of young ciscoes was investigated by Edsall and Colby (1970) who determined an upper lethal temperature of 78.8° F (26° C). Exploited cisco populations often exhibit wide fluctuations in numbers, sex ratios, and other features. A recent study by Clady (1967) reviewed such a population in Birch Lake, Mich. *See* also Carlander (1945), Scott (1951), and Smith (1956).

In keeping with its pelagic habitat, the lake herring is basically a plankton feeder but consumes a wide variety of foods. Larval ciscoes require light to feed and experimental evidence indicates that they begin to feed the day they hatch, while still carrying the yolk sac; dead zooplankton (*Cyclops*) are eaten at first (John and Hasler 1956). Studies of larval ciscoes in Lake Ontario by Pritchard (1930) indicated, however, that feeding commenced when about 10 days old, the food consisting of algae, copepods, and Cladocera. A detailed food study in Lake Nipissing (Langford 1938) showed that *Daphnia* and mayfly nymphs were important foods of adults in shallow water while *Diaptomus oregonensis* was the principal food in deep water. In the Great Lakes the crustaceans *Mysis* and *Pontoporeia*, copepods, and immature stages of aquatic insect groups, such as mayflies and caddisflies, were important adult food items (Pritchard 1931; Dryer and Beil 1964). Even flying ants, apparently eaten at the surface, were reported for Lake Huron specimens by Koelz (1929). In northern Saskatchewan, zooplankton, *Mysis*, midge and mayfly larvae, and water mites were important food items (Koshinsky 1965). But, food varies with the seasons and food studies conducted during spawning indicated that lake herring also eat their own eggs; they will also eat eggs of other species. Pritchard (1931) reported an average of 275 whitefish fry per stomach for lake herring feeding near a Lake Ontario hatchery outflow. And, on occasion, they will eat small minnows; indeed salted and live minnows are used as bait in winter angling through the ice.

In many respects, the lake herring is to aquatic predators what the rabbit is to its terrestrial counterparts, and forms part of the diet of a large number of fishes. The primary predator (except for man) is the lake trout, for which the lake herring is a preferred food.

It is also a common food of rainbow trout (Lake Simcoe), northern pike, burbot, yellow perch, and walleyes, when these species are present.

Bangham and Hunter (1939) examined 78 specimens of *C. artedii* from Lake Erie and found 30 fish parasitized. The cestode *Proteocephalus exiguus* was the dominant parasite, infecting 26 fish; cestodes *P. wickliffi* and *Abothrium crassum* were also present. One fish from the west end of the lake contained the nematode *Cystidicola stigmatura*.

Bangham (1941) found 15 of the 16 ciscoes taken from the deeper water of Proulx Lake in Algonquin Park, Ont., to contain parasites. He found the gill copepod *Ergasilus caeruleus* in large numbers. The immature stage of the cestode *Proteocephalus laruei* was present in four of the fish examined.

All 79 fish examined from Lake Huron waters by Bangham (1955) were infected. Parasites included 5 species of cestodes: *Proteocephalus laruei*, found in 71 fish; *Triaenophorus crassus* in 61 fish; *Diphyllobothrium* sp. in 54 specimens; and *P. exiguus* and *Abothrium crassum*. Other parasites identified were 2 species of nematodes (*Philometra* sp. and *Cystidicola stigmatura*), 2 of trematodes (*Diplostomulum* sp. and *Discocotyle salmonis*), 3 of copepods (*Salmincola inermis*, *S. wisconsinensis*, and *Argulus* sp.), 1 acanthocephalan (*Echinorhynchus salmonis*), and protozoan Myxosporidia.

Two hundred specimens of *C. artedii* from Lake Superior were examined for parasites by Warren (1951) who later described the occurrence of *Diphyllobothrium oblongatum* cysts in the flesh and demonstrated that they would develop to adult worms in herring gulls (Warren 1952).

C. artedii was described as a new host for the cestode *Cyathocephalus truncatus* in North America from specimens removed from the pyloric caeca of ciscoes caught in South Bay, Lake Huron (Dechtiar and Loftus 1965).

Hoffman (1967) listed trematodes (6), cestodes (10), nematodes (4), acanthocephalans (5), and crustaceans (7), parasites of *C. artedii* in North American waters.

In Lac la Biche, Alta., Paetz and Nelson (1970) attributed mass mortalities of this species, in part, to heavy gill infection by the copepod parasite *Ergasilus*.

The nutritive value of *C. artedii* was investigated by Klocke et al. (1947) who noted that lake herring (and burbot) could make a valuable contribution to the thiamine content of the American diet.

Relation to man The total value of this species to the Canadian economy would be exceedingly difficult to assess. Ecologically, it is of considerable importance for it is one of the main foods of the lake trout and may, at times, be important in the diet of other predaceous fishes. It is caught commercially by gillnets, but sometimes trapnets or seines are used. The Lake Erie fishery commonly used a floated (or canned) gillnet, thus catching the lake herring in its midwater habitat. Commercially caught ciscoes may be sold for the smoked fish trade, or as fresh or frozen fish, depending upon the fatness of the flesh. The flesh is usually of excellent flavour. It is also caught by sportsmen using spears, artificial lures, or live bait, and in the smaller lakes of the Great Lakes region may provide considerable sport for fly fishermen in the spring and a supplementary species for ice fishermen in winter.

In the Great Lakes, its abundance was described as unbelievable by numerous observers during the last century. For example, in 1868 the fishery overseer said that at Burlington Beach, Lake Ontario, "herring (alone which) frequent the bay in the month of November to spawn in unprecedented numbers of millions" (*see* Pritchard 1931). In the early 1900's the total yield of ciscoes from Lake Erie alone fluctuated around 20 million pounds annually, and in 1918 was over 48 million pounds. This fishery collapsed completely but as late as the 1950's approximately 20 million pounds were landed annually from the whole of the Great Lakes.

In northern Ontario and the western provinces, it is usually called tullibee, and may support a number of domestic fisheries for local consumption and as a food source for fur farms. It also supported extensive fisheries in Lake Winnipeg and other large lakes in Manitoba where important "tullibee" fisheries have been carried on for many years. Sometimes small local fisheries are conducted most efficiently only during the fall spawning runs.

In many parts of northern Canada it was an important winter food for native peoples and their dogs. Richardson (1836) remarked upon the fall fishery for ciscoes on Great Bear Lake and McPhail and Lindsey (1970) noted that a "herring" fishery was still in operation at Fort Franklin.

The lake herring was found to be a valuable source of thiamine by Klocke et al. (1947).

Nomenclature

Coregonus Artedi — Le Sueur 1818a: 231 (type locality L. Erie (at Buffalo) and Niagara R. (at Lewiston))
Coregonus albus — Le Sueur 1818a: 232
Salmo (*Coregonus*) *tullibee* (Richardson) — Richardson 1836: 201
Salmo (*Coregonus*) *Artedi* (LeSueur) — Richardson 1836: 203
Salmo (*Coregonus*) *harengus* (Richardson) — Richardson 1836: 210
Coregonus clupeiformis DeKay — Agassiz 1850: 339
Argyrosomus artedi (LeSueur) — Evermann and Smith 1896: 305
Argyrosomus tullibee — Evermann and Smith 1896: 320
Argyrosomus eriensis — Jordan and Evermann 1909: 165
Argyrosomus huronius — Jordan and Evermann 1909: 167
Leucichthys harengus (Richardson) — Jordan and Evermann 1911: 6
Leucichthys sisco (Jordan) — Jordan and Evermann 1911: 10
Leucichthys ontariensis — Jordan and Evermann 1911: 13
Leucichthys artedi (LeSueur) — Jordan and Evermann 1911: 17
Leucichthys eriensis (Jordan & Evermann) — Jordan and Evermann 1911: 20
Leucichthys supernas — Jordan and Evermann 1911: 22
Leucichthys manitoulinus — Jordan and Evermann 1911: 31
Leucichthys tullibee (Richardson) — Jordan and Evermann 1911: 32
Leucichthys macropterus — Bean 1916: 25 (*see* Smith 1964b)
Leucichthys nipigon — Koelz 1925: 1
Leucichthys nueltinensis new species — Fowler 1948: 142
Leucichthys churchillensis new species — Fowler 1948: 144
Coregonus artedii LeSueur — Scott 1967: 29

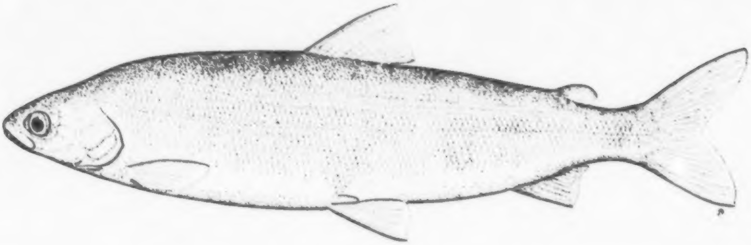
Etymology *Coregonus* — angle-eye, coined by Artedi from Greek words meaning pupil (of the eye), and angle; *artedii* — after Petrus Artedi, the "Father of Ichthyology," associate of Linnaeus and perhaps the ablest systematic zoologist of the 18th century.

Common names Cisco, lake herring, tullibee, freshwater herring, ciscoe, blueback, sand herring, shallowwater cisco, grayback tullibee, common cisco, Bear Lake herring, blueback tullibee, herring-salmon. French common name: *cisco de lac*.

The name tullibee is apparently derived from the name "ottonneebees" which Sir John Richardson (1836) attributed to the Cree Indians; he attributed the name tullibee to the fur traders.

ARCTIC CISCO

Coregonus autumnalis (Pallas)



Description Body elongate, length to about 12–15 inches (305–381 mm), less compressed laterally than most ciscoes, greatest body depth in front of dorsal fin, 20–23% of total length. Head moderate 22–24% of total length; eye moderate, its diameter 20–24% of head length; snout length usually slightly greater than eye diameter; mouth moderate, terminal, upper and lower jaws about equal, maxillary extending posteriorly to below anterior half of eye; a small cluster of teeth on tongue. Gill rakers, total count 41–48 (gill rakers on lower limb 26–30), longer than on *C. laurettae*, and slender. Branchiostegal rays 8 or 9. Fins: adipose dorsal present; dorsal 1, rays 10–12; caudal distinctly forked; anal rays 12–14; pelvic rays 11 or 12, a distinct pelvic axillary process present; pectoral rays 14–17. Scales cycloid, large, 82–110 in lateral line. Pyloric caeca 113–183. Vertebrae 64–67.

Nuptial tubercles developed on scales on flanks of males.

(*See also* McPhail 1966; McPhail and Lindsey 1970.)

Colour Overall colouration silvery; usually brown or green on the back, becoming silvery on sides and below. Anal and pelvic fins immaculate, pectoral fins lightly pigmented on upper surface; remaining fins lightly pigmented and dusky.

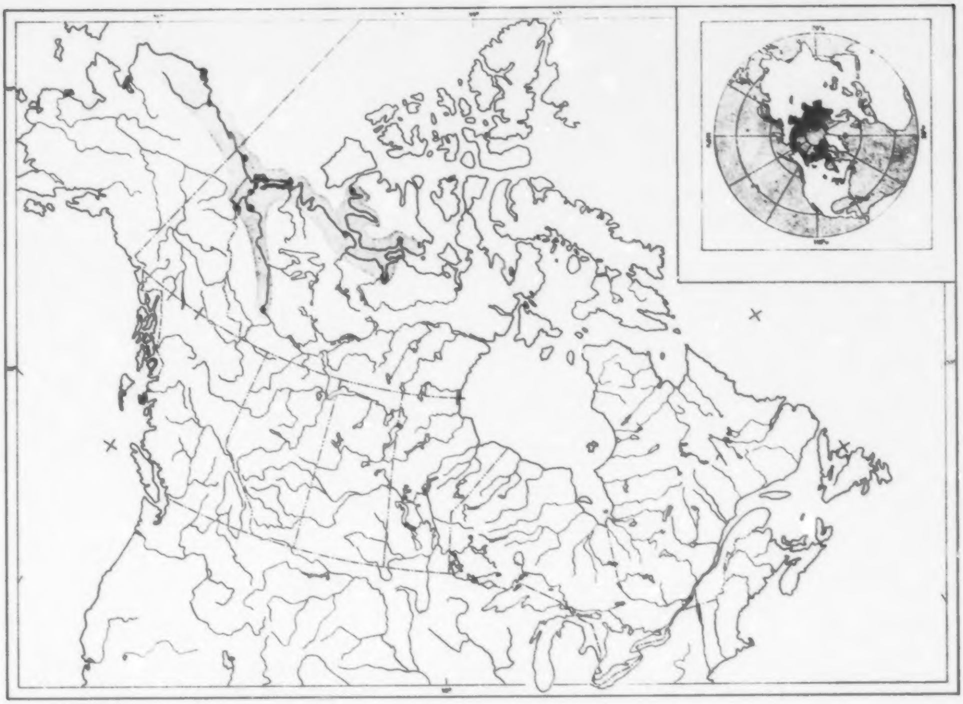
Systematic notes The species was described by Pallas (1776) as *Salmo autumnalis*, based on specimens from the Kara River, Siberia. North American populations are not distinguished taxonomically from those in Siberia. In North America, the arctic cisco has often been confused with *C. laurettae* and less frequently with *C. tullibee* (= *artedii*), hence, the literature must be treated with caution. *See C. laurettae* for further information and *also* McPhail (1966) and McPhail and Lindsey (1970).

Distribution The arctic cisco occurs in the coastal waters and lower parts of arctic rivers in Europe, Asia, and North America, from the White Sea region west to Alaska and the Northwest Territories.

In North America it occurs in the Arctic Ocean drainages from Point Barrow, Alaska, east along the arctic coastal waters and tributary rivers to Mackenzie delta, Cape Bathurst, Bathurst Inlet, and Cambridge Bay.

Biology The biology of the arctic cisco has received little or no study in northern Canada but the biology of Siberian populations is rather well known. It is an anadromous species. An upstream spawning migration takes place in summer in Siberia, usually beginning in July.

Spawning takes place over gravel beds, often in swiftly flowing water. Like all whitefishes the eggs are broadcast and abandoned by the parents. The egg number of Yenisei River fish was given by Nikol'skii (1954) as 7700–41,300. McPhail and Lindsey noted



that large females may carry 90,000 eggs. Adults apparently do not spawn every year in Siberian waters, and probably not in ours either. After spawning, the adults again move down river to the sea. On the Mackenzie River, Wynne-Edwards (1952) noted that it was "caught at Aklavik between freeze-up and Christmas presumably on its way out to sea, and ascending again in the early spring." The eggs presumably hatch in the spring and the young descend to the estuaries, as in Siberia. Maturity is attained in 5–7 years in some Siberian rivers, 9–10 in others, but no rate-of-growth studies have been made in Canada. Dymond (1943) said the arctic cisco attained a length of 12–18 inches (305–457 mm) and a weight of 3 pounds in Canada, but weights to 5½ pounds are reported from Siberian waters.

The arctic cisco behaves like a typical anadromous species, leaving the sea or estuarial waters in spring and summer, ascending freshwater rivers to spawn, and then moving down to the sea again. Although other whitefishes may also move into salt water, such as the lake herring and lake whitefish in Hudson Bay, none seem to spend more time at sea than the arctic cisco, although admittedly the waters it frequents are less saline than those off the Atlantic or Pacific coasts.

In Siberia, the food consists mainly of crustaceans, such as *Mysis* and *Pontoporeia*, and small fishes, such as young sculpins, smelt, and whitefish.

Lawler (1970) listed those parasites attacking *C. autumnalis* in waters of the USSR as compiled by Bykovskaya-Pavlovskaya et al. (1962) and discussed their effect. Information on parasites in North American arctic ciscoes is lacking.

Relation to man The arctic cisco is a common and valuable food fish throughout its range. In Siberia it is an important commercial species and is usually fished during its summer migration in rivers. It was also regarded as a valuable food fish in the lower Mackenzie River, according to Dymond (1943), who noted that it was well liked as human food and equal to whitefish as dog food, and that at Arctic Red River, it was caught, dried, and smoked in great numbers every summer by the Indians. Wynne-Edwards (1952) noted that it formed the principal object of a summer fishery at The Ramparts on the Mackenzie.

Nomenclature

Salmo (*Coregonus*) *autumnalis*	— Pallas 1776: 32 (type locality Pechor and Enissei rivers of western Siberia)
Leucichthys autumnalis (Pallas)	— Dymond 1943: 228
Coregonus autumnalis (Pallas)	— Walters 1955: 279
	— McPhail 1966: 146

Etymology *Coregonus* — angle-eye, coined by Artedi from the Greek words meaning pupil (of the eye), and angle; *autumnalis* — of the autumn.

Common names Arctic cisco, salmon-herring. French common name: *cisco arctique*.

BLOATER

Coregonus hoyi (Gill)

Description Body elongate, average total length about 8–10 inches (203–254 mm) or greater, depending on lake, distinctly compressed laterally and thin, greatest body depth in front of dorsal fin, 17–24% of body length. Head long, 23–27% of total length; eye small, its diameter 22.8–26.4% of head; snout length greater than eye diameter, usually rather short or pointed; mouth terminal, lower jaw usually protruding beyond upper and with a distinct tubercle at the tip, maxillary extending posteriorly to below the anterior half of eye. Gill rakers total count 38–50 (Lake Ontario), 37–48 (Lake Michigan), 37–47 (Lake Huron), 37–49 (Lake Superior), 40–48 (Lake Nipigon). Branchiostegal rays 8 or 9 (Lake Superior). Fins: small dorsal adipose present, all rayed fins are long; dorsal 1, rays 9–11; caudal distinctly forked; anal rays 11 or 12; pelvic rays 11; pectoral rays 15 or 16. Scales cycloid, large, 63–84 in lateral line. Vertebrae 55–57.

Nuptial tubercles developed on scales on sides of males and at least some females.

(*See also* Dymond 1926; Koelz 1929; Pritchard 1931.)

Colour Overall colouration silvery with some pink or purple iridescence and a greenish tinge above the lateral line. Ventral surface silvery white. Weak pigmentation on head including cheeks and tip of lower jaw. Fins usually weakly pigmented, although dorsal and caudal fins dark edged; pelvics usually immaculate.

Systematic notes This is the smallest of the endemic deepwater ciscoes. It was named, but not described, by Gill (*in* Hoy 1872) in honour of Dr P. R. Hoy who had sent him the specimen. *See* Koelz (1929, p. 312) for additional details. Koelz (1929) selected a lectotype, a mutilated specimen 5.4 inches (137 mm) long, probably collected in Lake Michigan, off Racine, Wis., in March 1872, by Hoy. This specimen, and a cotype, both in poor condition, are stored in the United States National Museum, cat. no. 8902.

The populations differed slightly in meristic and morphometric values from lake to lake, but not sufficiently to warrant taxonomic recognition. The changes in population structure in most of the Great Lakes have resulted in morphological changes in some lakes, especially Lake Michigan.

Distribution *Coregonus hoyi* has generally been considered endemic in the Great Lakes basin where it occurs in all lakes, including Lake Nipigon, except Lake Erie. There is also a report of a single specimen, identified as this species, from Eva Lake, Rainy River District, Ont., (Lindeborg 1941). But, since the record is based on a single specimen only 3.0 inches (76 mm) long, more material should be examined and the identity confirmed.

Biology Spawning generally takes place in February and March for all lakes covered by observations, but many observers remarked that some spawning must occur throughout the year (Jobes 1949b; Dryer and Beil 1968). In almost every month of the year a few ripe, nearly ripe, or spent males and females have been caught. They apparently spawn over almost all bottom types in depths from about 120 to 300 feet (36–91 m).

Information on number and size of eggs was provided for Lake Superior by Dryer and Beil (1968), based upon samples collected during 1964–1965. Study of 20 females ranging in average length from 8.4 inches (213 mm) to 11.7 inches (297 mm), yielded a range in total number of eggs from 3116 to 12,045. The larger females had the greater number of eggs, but the average number of eggs per ounce of fish was 1241. Over the whole size-range studied, the number of eggs per ounce of fish showed little variation. Bloaters produced about 60% more eggs than *C. artedii* of the same size. These data should not be interpreted as representative of the pre-1950 *hoyi* populations in the Great Lakes when the growth rates and maximum size attained were less than during the period of Dryer and Beil's study.

The eggs are relatively large, with an average diameter of 1.95 mm, based upon examination of 160 eggs from eight females. These figures for egg diameter, given by Dryer and Beil, presumably referred to eggs removed directly from the ovary of the female, not to eggs released into the water, with subsequent uptake of water and increase in diameter.

Studies of embryological development and larval descriptions have apparently not been published, but much information on larval bloaters in Lake Michigan was given by Wells (1966). Collections of larval *hoyi* were made with special nets, from April through August, 1964. Although the total lengths of the larvae ranged from 8.6–14.9 mm, the average length of the samples taken throughout the period remained remarkably uniform, ranging from 11.0–11.3 mm. Wells concluded that the unchanging size composition and small size of the larvae suggested that the sampling followed closely the progress of hatching, that the method was selectively sampling the 10–12 mm size-range, and that larger larvae evaded capture. Even so, it was the first successful attempt to study the free larval stages of any Great Lakes endemic deepwater cisco and was possible only because *C. hoyi* was practically the only deepwater cisco remaining in Lake Michigan. Despite the number of larvae collected information on larval growth was not available because of the selective nature of the sampling and the difficulty of capturing larger larvae.

The bloater was traditionally the smallest and had the slowest growth rate of any of the endemic deepwater ciscoes, but the growth rate varied from lake to lake. The average total length in Lake Michigan was about 8 inches (203 mm) according to Smith (1964a), and in Lake Ontario (south shore) was about 10 inches (254 mm), (Stone 1947). But, it was only in these two lakes that it grew regularly over 8 inches (203 mm) long, and hence supported a commercial fishery (Koelz 1929).

Growth studies of larger bloaters have been conducted for Lake Ontario (Stone 1947), Lake Michigan (Jobes 1949b), and Lake Superior (Dryer and Beil 1968). The earlier studies reflected the situation prior to the tremendous changes in growth rate and body form that followed the disappearance of lake trout and larger coregonine fishes, while the Lake Superior study demonstrated the changes evident even in the post-1950 period. (*See* table below.)

Females usually lived longer and attained a larger size than males, but the latter usually matured earlier. In Lake Ontario, females lived to age 10 or 11 while males lived only to age 9 (Stone 1947). In Lake Superior, Dryer and Beil (1968) noted that for populations of the 1958–1965 period, some males attained age 10, females age 11. The commercial catch was usually dominated by age 6 fish during the same period.

Considerable attention has been directed to the apparent predominance of females among bloater populations in Lake Michigan in recent years. Brown (1970) summarized the existing data and showed that the percentage of females increased from 72% of fish sampled in 1928–1932 to 95% in 1963 and 94–97% during the period 1964–1969. Brown suggested that the many biological changes evident in Lake Michigan populations (size, growth rate, sex ratio plus morphometric changes) may have indicated the beginning of a serious population decline. It is perhaps significant that Stone (1947) noted that the percentage of females in Lake Ontario in 1942 was 81.9%. Dryer and Beil (1968) also remarked upon this phenomenon and listed the Great Lakes coregonines for which it had been reported. No explanations of the mechanisms involved have been advanced for coregonines, but it is interesting that sea lamprey populations in the upper Great Lakes also exhibited considerable variation in sex ratios during the period of population expansion and subsequent habitat saturation. *See* Applegate and Thomas (1965) for further information.

The bloater lives in shallower water than the other deepwater ciscoes. Koelz (1929) reported that in Lake Michigan it was occasionally caught in poundnets at depths as shallow as 30 feet, but this seldom occurred in Canadian waters. In Lake Ontario, Pritchard noted that it ranged at all depths from 125 to 400 feet (38–121 m) and reached maximum abundance at 250–300 feet (76–91 m). In Lake Nipigon, Dymond (1926) considered it to have the most limited vertical range of any cisco in the lake, since it was restricted to depths of 90–330 feet (27–100 m).

Information for the other Great Lakes is more or less in agreement. It was generally considered rare or uncommon beyond 420

		Age (*years*)										
		1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+
L. Ontario (Pritchard 1931)	FL											
	inches	6.1	6.9	8.2	9.1	9.7	11.1	–	–	–	–	–
	mm	155	175	208	231	246	282	–	–	–	–	–
	Wt (*oz*)	1.1	1.8	3.1	4.1	4.9	7.7	–	–	–	–	–
L. Ontario (Stone 1947)	TL											
	inches	–	–	8.3	8.7	9.3	9.8	10.1	10.6	11.1	11.4	12.4
	mm	–	–	210	221	237	249	256	268	287	291	315
L. Michigan (Jobes 1949b)	TL (*inches*)											
	M	–	7.0	7.4	8.4	9.1	9.8	10.6	–	–	–	–
	F	–	6.9	7.6	8.4	10.0	10.1	10.9	–	–	–	–
	TL (*mm*)											
	M	–	178	188	213	231	249	269	–	–	–	–
	F	–	175	193	213	254	257	277	–	–	–	–

feet (128.0 m) but reached a maximum depth of about 600 feet (183.0 m) in the deep upper lakes. In Lake Michigan, Jobes (1949b) found maximum abundance to occur at about 120–350 feet (36.6–108.0 m).

Recently, Wells (1966) provided unique and valuable information on larval bathymetric distribution for Lake Michigan. The larvae occurred over a wide depth range, usually near bottom. About 83% of all larvae were caught at depths between 240 and 360 feet (73.2–109.7 m) but were most abundant between 300 and 360 feet (91.4–109.7 m). About 96% were taken at levels at which the maximum temperature did not exceed 40.5° F (4.7° C).

The food consists mainly of *Mysis relicta* and *Pontoporeia affinis*. Pritchard (1931) examined 58 bloater stomachs from Lake Ontario and indicated that these two organisms, with the addition of copepods and small molluscs, constituted the main food. But the most complete recent report was a quantitative study by Wells and Beeton (1963) for Lake Michigan bloaters. These authors examined nearly 2000 stomachs. Fish under 7 inches (178 mm) long ate mainly zooplankton, especially *Cyclops bicuspidatus* and *Diaptomus* spp., and only a few (less than 10%) *Pontoporeia* and *Diaptomus* spp. But, as the fish became larger they consumed more *Pontoporeia* and *Mysis*. The amphipod *Pontoporeia* was, on the whole, the more important of the two, having an average percentage occurrence of 60.7, that for *Mysis* being 48.2. It was more important in shallower waters, down to about 160 feet or 49.4 m but below this depth, *Mysis* became increasingly important. *Pontoporeia* lives primarily on bottom, *Mysis* just off bottom by about 3 feet (0.9 m) hence, it would seem that large *hoyi* fed on or near the bottom in Lake Michigan.

In contrast to the Lake Michigan study, Dryer and Beil (1968) concluded that in Lake Superior *C. hoyi* was primarily a pelagic feeder. The order of frequency of food items in over 300 stomachs was copepods, *Mysis* and *Pontoporeia*, the order by volume was *Mysis*, copepods, and *Pontoporeia*. Fish eggs and fingernail clams were also eaten, and the authors considered these to be evidence of occasional bottom feeding although fish eggs seemed to be a regular part of the diet. At depths of 260–360 feet (79–110 m) 5 of 9 stomachs contained fish eggs, to a maximum of 130 in one stomach.

The major natural predator on the bloater was probably the lake trout, before the trout's decimation by the sea lamprey. The total consumption of bloaters by lake trout must have been enormous. For example, Hile and Buettner (1955) estimated that at least 30 million pounds of bloaters were eaten annually by lake trout in Lake Michigan to support a yearly commercial yield of 6 million pounds of trout. Bloaters were also eaten by burbot (Van Oosten and Deason 1938) but to a much lesser extent.

The bloater was considered by Pritchard (1931) to be one of the most heavily parasitized of Lake Ontario ciscoes. He recorded bothriocephalid larvae (tapeworms), the nematode *Cystidicola* sp. (in 40% of specimens) and the copepod *Salmincola inermis* (about 20% of specimens).

Bangham (1955) examined 47 specimens of *C. hoyi* from Lake Huron and found all infected. Parasites included trematodes *Diplostomulum* sp., in 24, and *Discocotyle salmonis* in 5, cestodes *Diphyllobothrium* sp. in 26, *Proteocephalus exiguus* in 13, *P. laruei* in 32, and *Triaenophorus crassus* in 17, nematode *Cystidicola stigmatura* in 4, acanthocephalans *Echinorhynchus leidyi* in 4, and *E. salmonis* in 18, and the crustacean *Salmincola wisconsinensis* in one.

Hoffman (1967) added the cestode *Cyathocephalus americanus* and the leech *Piscicola milneri* to the list of parasites of this species in North American fresh waters.

Relation to man The bloater has never been a valued species in the Canadian commercial fishery on the Great Lakes, in contrast to its utilization in certain United States waters. The extent to which the bloater contributed to the Lake Huron chub fishery during the early 1960's is unknown, although it may have been significant. Practically the only chub fishery in Canadian waters of the

Great Lakes was that in Lake Huron. The figures tell an all too familiar story of declining yields. The following table for Lake Huron shows the landings (in pounds) of "chubs" *Coregonus* (*Leucichthys* spp.) exclusive of *Coregonus artedii*. The increasing poundage from Georgian Bay probably reflects a transfer of effort from the depleted Lake Huron stocks to the limited reserves in Georgian Bay.

Year	L. Huron (exclusive of Georgian Bay)	Georgian Bay	Total
1961	2,341,528	31,393	2,372,921
1962	2,180,123	81,515	2,261,638
1963	1,668,729	104,122	1,772,851
1964	1,442,020	120,654	1,562,674
1965	1,083,035	408,552	1,491,587
1966	652,614	285,503	938,117

In Lake Ontario, the bloater was not considered commercially important in Canadian waters (Pritchard 1931) although it constituted the bulk of the United States commercial catch of deepwater ciscoes (Stone 1947).

During the early years of the chub fishery throughout the Great Lakes, the bloater was spurned because of its small size, but it became increasingly important after 1950. This was particularly true in Lake Michigan where annual catches fluctuated between 5 and 12 million pounds during the 1960's. The catches declined in 1963 and 1964 as a result of botulism scare in 1963, according to Smith (1968). The reported outbreaks of botulism were attributed to improperly processed chubs, composed mainly of *Coregonus hoyi*. An improved process of smoking at a higher temperature eliminated the problem (Bratzler and Robinson 1967).

The bloater was also of great importance as a forage fish for the lake trout, as indicated under the *Biology* section.

Nomenclature

Argyrosomus hoyi — Gill (*in* Hoy 1872: 99) (type locality Lake Michigan off Racine, Wis.)
Argyrosomus prognathus — Evermann and Smith 1896: 314
Leucichthys hoyi Gill — Hubbs 1926: 13
— Koelz 1929: 449
Coregonus hoyi (Gill) — Hubbs and Lagler 1958: 54
— Scott 1967: 31

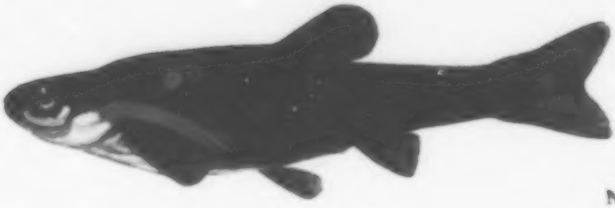
Etymology *Coregonus* — angle-eye, coined by Artedi from the Greek words meaning pupil (of the eye), and angle; *hoyi* — after Dr P. R. Hoy of Racine, Wis., naturalist who collected fishes of Lake Michigan.

Common names Bloater, bloat, Hoy's cisco. French common name: *cisco de fumage*.

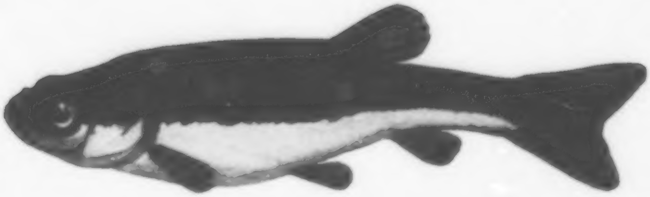
DEEPWATER CISCO

Coregonus johannae (Wagner)

Description Body elongate, average total length about 11.4 inches (290 mm), moderately compressed laterally, greatest body depth in front of dorsal fin, about 22–27% of total length. Head relatively long, 22.8–26.4% of total length; eye moderate,



Northern redbelly dace



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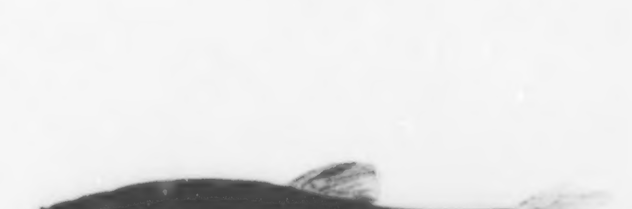


Finescale dace

Finescale dace

shorter than snout; snout narrow, elongate, 25–31% of head length; mouth terminal, lower jaw usually equal to upper jaw but may be longer or shorter; maxillary extending posteriorly to below anterior portion of eye but not reaching centre of eye. Gill rakers relatively long, 26–36 (Lake Michigan), 25–35 (Lake Huron), usually 10–12 on upper limb of the arch, 17–20 on lower limb. Branchiostegal rays 8 or 9 (Lake Huron). Fins: small dorsal adipose present; dorsal 1, rays 9–11; caudal distinctly forked; anal rays 10–16; pelvic rays 11 or 12; pectoral rays 14–20 (Lake Michigan), 15–19 (Lake Huron). Scales cycloid, large, 74–95 in lateral line. Vertebrae 56–58.

Nuptial tubercles (pearl organs) developed on breeding males. (*See* Koelz 1929).

Colour Overall colouration silvery with pink or purple iridescence. Pale blue or green on the back, becoming blue-green on the sides. Ventral surface silvery white. Pigmentation on premaxillaries and on top of head. Fins mainly clear or white, translucent, with lightly scattered pigmentation, pelvics immaculate.

Systematic notes This deepwater species, the largest of the endemic ciscoes, was described by Wagner (1910). The holotype is a ripe male, 10.5 inches (265 mm) in length, caught in Lake Michigan, about 18 miles off Racine, Wis., on July 3, 1906. It is stored in the United States National Museum, cat. no. 87353. When examined in 1959, the specimen was in fair condition and when remeasured had a total length of 12.5 inches (315 mm).

The populations in Lake Huron apparently had fewer lateral line scales, more pectoral rays, longer head, longer snout, longer paired fins, and were more pigmented than those from Lake Michigan.

Distribution The deepwater cisco was indigenous to the Great Lakes basin and occurred only in the deeper portions of lakes Huron and Michigan. No specimens have been seen in Lake Michigan since 1951 (Moffett 1957) and, although it is rare in Lake Huron, its actual status is unknown.

Biology The reproductive or spawning phase of the life history of the deepwater cisco is most imperfectly known and, considering its extinction in Lake Michigan and rarity in Lake Huron, it is unlikely that our meagre knowledge will be expanded.

In Lake Huron, spawning apparently occurred between mid-August and the end of September, according to the observations available to Koelz (1929). He reported that females with well-developed eggs, and one with ripe eggs, were taken off Wiarton and Lion's Head, Georgian Bay, on July 28 and 30, 1919. Examination of other catches made in Georgian Bay and off Alpena, Mich., which included ripe or spent females and males with pearl organs, led to the conclusion that spawning commenced in August and ended before the last of September. Spawning grounds were never found. Koelz also considered the possibility that some females may have spawned every second year, a suggestion not applied to ciscoes in any other Great Lakes.

Information on other aspects of the life history of *johannae* is also meagre, and we know next to nothing of their fecundity, embryology, early life history, or rate of growth. Ages can be determined from scales and doubtless scale samples are filed away in government laboratories. Mature specimens smaller than 6.5 inches (165 mm) were not found, and most specimens 7.7 inches (195 mm) in length were mature (Koelz 1929).

This species was regarded as the largest of the endemic deepwater ciscoes and in Lake Michigan was said to average about 11.4 inches (290 mm) in length and to have a maximum weight of about 1.5 pounds. Among the Lake Michigan chubs, it was exceeded in size only by the blackfin cisco (*Coregonus nigripinnis*).

In Lake Huron, the limits of depth distribution for nonspawning fish were given as 96–600 feet (29.3–182.9 m), but this cisco was caught rarely at depths shallower than 210 feet (64.0 m), and maximum abundance occurred at 300–480 feet (91.4–146.3 m). The maximum depth range was not known and may have been greater than 600 feet (Koelz 1929).

The only information on food seems to be that provided by Koelz (1929) for Lake Huron fish. Of 34 stomachs examined, 80–100% of the food ingested consisted of *Mysis*, with small quantities of *Pontoporeia* and fingernail clams (*Pisidium*) making up most of the remainder. A few aquatic insects and fish scales were also observed, and about half of all specimens had ingested sand, cinders, and wood fragments.

The only parasites reported for the deepwater cisco were the larval form of the nematode *Dacnitoides cotylophora* and the crustacean *Achtheres corpulentus* (Hoffman 1967).

Relation to man This was the largest of the endemic deepwater ciscoes of the Great Lakes and one of the species preferred by the chub fishery; consequently, fishing pressure on it was intense. The final extinction of *johannae* from Lake Michigan is usually attributed to the combination of heavy commercial exploitation and predation by the sea lamprey during the 1940's. In any case, *johannae* has not been seen in Lake Michigan since 1957. Its status in Lake Huron is not known to us, but it is presumed to be rare.

Nomenclature

Argyrosomus johannae — Wagner 1910: 957 (type locality Lake Michigan, off Racine, Wis.)
Argyrosomus hoyi — Evermann and Smith 1896: 310
Leucichthys johannae (Wagner) — Hubbs 1926: 13
Coregonus johannae (Wagner) — Hubbs and Lagler 1958: 55
— Scott 1967: 31

Etymology *Coregonus* — angle-eye, coined by Artedi from the Greek words meaning pupil (of the eye) and angle; *johannae* — after "life-companion" of George Wagner.

Common names Deepwater cisco, deepwater chub, the chub. French common name: *cisco de profondeur*.

KIYI

Coregonus kiyi (Koelz)

Description Body elongate, average total length about 10 inches (254 mm), distinctly compressed laterally, and thin, greatest body depth in front of dorsal fin 20–30% of body length. Head about 23–26% of total length; eye large, but shorter than snout, its diameter 22.2–26.4% of head length; snout always longer than eye; mouth terminal, lower jaw usually projecting beyond upper, usually with a distinct symphyseal knob or projection, maxillary pigmented and extending posteriorly to below the anterior half of eye. Gill rakers, total count 39–47 (Lake Ontario), or 34–45 (Lake Michigan). Branchiostegal rays 8 or 9 (Lake Superior, Koelz 1929). Fins: small dorsal adipose present, all rayed fins are long; dorsal 1, rays 9–11; caudal distinctly forked; anal rays 9–16; pelvic rays 11 or 12, pelvic axillary scale present; pectoral rays 15–18. Scales cycloid, large, 71–91 in lateral line. Vertebrae 55–58.

Nuptial tubercles or pearl organs developed on breeding males.

The description of this species is based mainly on Lake Ontario specimens (Pritchard 1931); the anal ray count is from Lake Michigan specimens (Koelz 1929).

Colour Overall colouration silvery with pink or purple iridescence, dark on back, silvery on sides, and white below; often dark on tip of lower jaw, top of head, back, and on dorsal and caudal fins. Pelvics usually immaculate.

Systematic notes This deepwater form is endemic to the Great Lakes and was described by Koelz (1921). The holotype is a female, 7.5 inches (191 mm) in length to base of caudal fin, caught in Lake Michigan August 23, 1920, and stored in the United States National Museum, cat. no. 84100. Koelz (1929) assigned the Lake Ontario form to the subspecies *orientalis*, and assigned those in lakes Huron, Michigan, and Superior to the typical subspecies *C. kiyi kiyi*. The characters said by Koelz to distinguish the Lake Ontario subspecies were: higher number of gill rakers, shorter paired fins, and a shorter head. However, the distinctions are of little more than academic interest since the species has become exceedingly scarce, if not extinct, at least in lakes Ontario and Michigan.

Distribution The *kiyi* was indigenous to the Great Lakes basin and was limited in distribution to the deeper waters of lakes Ontario, Huron, Michigan, and Superior. It has been greatly reduced in numbers in most of these lakes and may even be absent. It is still present in Lake Superior.

Biology Some of the first investigations suggested considerable differences in time of spawning from lake to lake but gonads of individual deepwater ciscoes of many species may become prematurely ripe. This condition can be misleading, especially if only a few specimens are available.

This species has a rather prolonged spawning period that may extend from November to January. In Lake Ontario, spawning was reported to have commenced in late October, 1926, and to have continued as late as January 8, 1927. In Lake Superior, it takes place usually in November or December. In 1959, of kiyi caught between November 23 and December 6, 50% were ripe.

Spawning probably took place at depths of 300–550 feet (91.4–167.6 m) at temperatures ranging from 35.0°–38.0° F (1.7°–3.4° C). Data on fecundity, embryological development, and early life history are scarce or altogether wanting. Scale formation commenced at a total length between 27.2–32.2 mm (Hogman 1970).

Age analysis, using scales, indicated that growth was relatively slow. Lengths at ages from 1 to 8 for the former Lake Ontario and Lake Michigan populations are given below.

				Age (*years*)						
				2+	3+	4+	5+	6+	7+	8+
L. Ontario (Pritchard 1931)	FL	*inches*		7.5	8.5	9.7	10.6	11.9	–	–
		mm		190	216	246	269	302	–	–
		Wt (*oz*)		2.9	4.4	5.9	7.3	10.7	–	–
L. Michigan (Deason and Hile 1947)	TL	*inches*	M	9.9	9.7	10.1	10.4	10.5	10.1	11.4
			F	10.1	10.1	10.4	10.7	10.9	11.2	10.6
		mm	M	251	246	257	264	267	257	290
			F	257	257	264	272	277	284	269

The kiyi is one of the smallest of the chubs, averaging about 10 inches (254 mm) long and 6 ounces (170 g) in weight. At a given age, females were usually heavier than males. Females lived longer, to at least age 10, compared to 8 years for males, but the age attained varied slightly in different lakes.

This deepwater species was usually said to live at depths of 30–100 fathoms or 180–600 feet (54.9–182.9 m) but, in general, it occurred most frequently in depths over 300 feet. In Lake Ontario, Pritchard (1931) noted that kiyi seldom came into water less than 250 feet deep, and that it reached maximum abundance at about 410 feet. In Lake Superior, information gathered during 1958–1963 suggested that the species was abundant at about depths of 600 feet.

The crustacean *Mysis relicta* and the amphipod *Pontoporeia hoyi* were the most common food items of the Lake Ontario populations studied by Pritchard (1931), and *Mysis* was reported as the principal food of Lake Huron *kiyi* by Koelz (1929). *Mysis* was also considered to be an important food in Lake Michigan but constituted only 30.3% of ingested food, compared with *Pontoporeia*, which made up 69.7% (Bersamin 1958). As many as 202 *Mysis* were found in one kiyi stomach from Lake Michigan.

The nematode *Cystidicola* sp. was the only parasite reported from Lake Ontario by Pritchard (1931). Hoffman (1967) listed a crustacean, *Salmincola inermis*, and the larval form of the cestode *Diphyllobothrium* sp.

Relation to man The species was commercially important in Lake Ontario in the 1920's and 1930's, but no specimens have been reported for many years. It is possibly present in numbers in Lake Superior but has largely disappeared from Lake Michigan. Its status in Lake Huron is unknown. (*See also* p. 231.)

Nomenclature

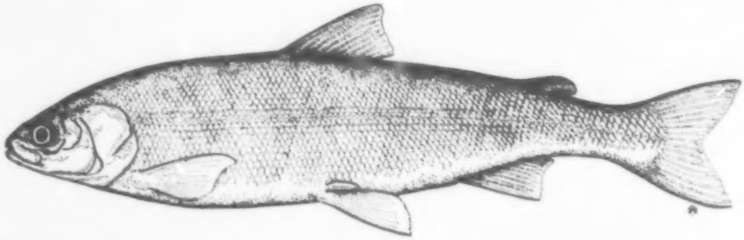
Leucichthys kiyi	— Koelz 1921: 1 (type locality 12 miles ExS of mouth of the Sturgeon Bay Ship Channel in Lake Michigan)
Coregonus kiyi (Koelz)	— Hubbs and Lagler 1958: 55
	— Scott 1967: 32

Etymology *Coregonus* — angle-eye, coined by Artedi from the Greek words meaning pupil (of the eye) and angle; *kiyi* — name used by "chub" fishermen of Lake Michigan.

Common names Kiyi, chub, waterbelly, mooneye. French common name: *cisco kiyi*.

BERING CISCO

Coregonus laurettae Bean



Description Body elongate, length to about 12 inches (305 mm), less compressed laterally than most ciscoes, greatest body depth in front of dorsal fin, about 20% of total length. Head moderate, 22–25% of total length; eye moderate, its diameter 20–25% of head length; snout length about equal to eye diameter; mouth moderate, terminal, upper and lower jaws about equal, maxillary broad, and long, extending posteriorly to below middle of eye; a small cluster of teeth on tongue. Gill rakers, total count 33–40 (gill rakers on lower limb 21–25), shorter than on *C. autumnalis*. Branchiostegal rays 8 or 9. Fins: adipose dorsal present; dorsal 1, rays 11–13; caudal distinctly forked; anal rays 12–14; pelvic rays 10–12, a distinct pelvic axillary process present; pectoral rays 14–17. Scales cycloid, large 76–95 in lateral line. Pyloric caeca 71–123. Vertebrae 62–65.

Nuptial tubercles probably developed on males but no direct evidence.

(*See also* McPhail 1966; McPhail and Lindsey 1970.)

Colour Overall colouration silvery; generally brown or green on the back, becoming silvery below. Anal, pelvic, and pectoral fins immaculate or nearly so; dorsal and caudal fins lightly pigmented and dusky.

Systematic notes The species was described by Bean (1882). No holotype was designated but the cotypes, four in number, (USNM cat. no. 27695) were collected at Point Barrow, Alaska, and an additional co-type (USNM cat. no. 27915) was collected at Port Clarence, Alaska. Many authors have regarded *C. laurettae* as a synonym of *C. autumnalis* (Dymond 1943; Walters 1955) but the validity of *laurettae* was recently established by McPhail (1966) using the gill rakers on the lower limb of the first gill arch as the primary character. *C. laurettae* had 21–25 gill rakers on the lower limb, *C. autumnalis* 26–30 rakers on the lower limb. On re-examination of the Point Barrow types, McPhail noted that two were *C. autumnalis* (*sensu latum*) and one was *laurettae*; he, therefore, selected the Port Clarence specimen (gill raker count 14 + 23) as the lectotype. The form *Argyrosomus alascanus*, described by Scofield (1899) was considered by Jordan and Evermann (1911) and Dymond (1943) as a synonym of *C. laurettae*, with which McPhail agreed. He also discussed the origin of *C. laurettae* and *C. autumnalis*, noting their morphological similarity and probable common ancestry.

Distribution Restricted to extreme northwestern North America but may occur in northeastern Siberia, although not reported. The Bering cisco is known only from Alaska, where it occurs along the coast and in rivers from Cook Inlet on the Pacific slope to near the mouth of the Colville River, Beaufort Sea. Conceivably, it may be found in the coastal waters of the Yukon Territory.

Biology As noted by McPhail and Lindsey (1970) little or nothing is known of the biology of this species. It is a coastal form and is probably anadromous. The above authors suggested that it probably ascends rivers in late summer, spawns in early autumn and, after spawning, moves downstream. There is no information on age, growth, or maximum size but most specimens are of the order of 10–13 inches (254–330 mm) in total length. The meagre available evidence indicated that food consisted of crustaceans.

Relation to man It is possibly a good food fish and may be used by local people but because of its relatively small size, is not caught regularly in the gillnets in common use.

Nomenclature

Coregonus laurettae — Bean 1882: 156 (type locality Point Barrow, Alaska)
Argyrosomus laurettae (Bean) — Jordan and Evermann 1896–1900: 471
Leucichthys alascanus (Scofield) — Jordan and Evermann 1911: 16
Leucichthys laurettae (Bean) — Jordan, Evermann, and Clark 1930: 62
Argyrosomus alascanus Scofield — McPhail 1966: 146

Etymology *Coregonus* — angle-eye, coined by Artedi from the Greek words meaning pupil (of the eye), and angle; *laurettae* — named for Mrs Lauretta H. Bean.

Common names Bering cisco, lauretta, herring, freshwater herring, lake herring, tullibee. French common names: *cisco de l'Alaska, cisco du Béring.*

BLACKFIN CISCO

Coregonus nigripinnis (Gill)

Description Body elongate, average total length about 13 inches (330 mm) in upper Great Lakes, distinctly laterally compressed, and deep, maximum body depth in front of dorsal fin, 25–29% of total length, body width about half body depth. Head broadly triangular, 21.3–26.4% of total length; eye large, its diameter 21.8–25.0% of head length; snout blunt, its length usually greater than eye diameter, 24.4–28.6% of head length; mouth terminal, lower jaw usually projecting beyond upper, sometimes equal to upper jaw, maxillary pigmented, and extending posteriorly to below anterior edge of pupil. Gill rakers, total count 41–52 (Lake Michigan), 40–52 (Lake Huron), 36–48 (Lake Superior), 44–54 (Lake Nipigon), 41–54 (Lake Winnipeg). Branchiostegal rays 8–10 (Lake Michigan), 9 (Lake Superior). Fins: small dorsal adipose present, all rayed fins rather long; dorsal 1, rays 9–11; caudal widely spread and deeply forked; anal rays 10–13; pelvic rays 11 or 12, pelvic axillary scale present; pectoral rays 15–18. Scales cycloid, large, 74–89 in lateral line. Vertebrae 56–59.

Nuptial tubercles or pearl organs developed on breeding males and on some females.

This description is based primarily on Koelz' (1929) description of *nigripinnis* from

Lake Michigan, the type locality, although it is now extinct there.

(*See also* Koelz 1929; Dymond 1926; Dymond and Pritchard 1930.)

Colour Overall colouration dark silvery, with pink or purple iridescence on the sides, back dark green to black and silvery below. Maxillary and mandible whitish but heavily pigmented. All fins typically black, particularly on outer half. The species is usually characterized by darkly pigmented fins and the deep body. *See* colour illustration facing p. 90.

Systematic notes The blackfin cisco was named by Gill (*in* Hoy 1872) from a specimen caught in Lake Michigan and sent to him by P. R. Hoy. The type was not extant according to Koelz (1929). The variability of *nigripinnis* in the Great Lakes convinced Koelz of the need to recognize four subspecies, as follows:

Coregonus nigripinnis nigripinnis (Gill)
— Lake Michigan
— Lake Huron
Coregonus nigripinnis regalis (Koelz)
— Lake Nipigon
Coregonus nigripinnis cyanopterus (Jordan and Evermann)
— Lake Superior
Coregonus nigripinnis prognathus Smith
— Lake Ontario

The Lake Ontario subspecies, *C. n. prognathus*, was erected on the basis of a single specimen which is stored in the United States National Museum (*Coregonus prognathus* Smith, cat. no. 45568). When examined in 1959, it was in good condition but had been eviscerated and the gill arch had been damaged. We were able to count 42 gill rakers (15 + 27) but the end of the upper arch was missing and presumably the complete count would be greater than 42.

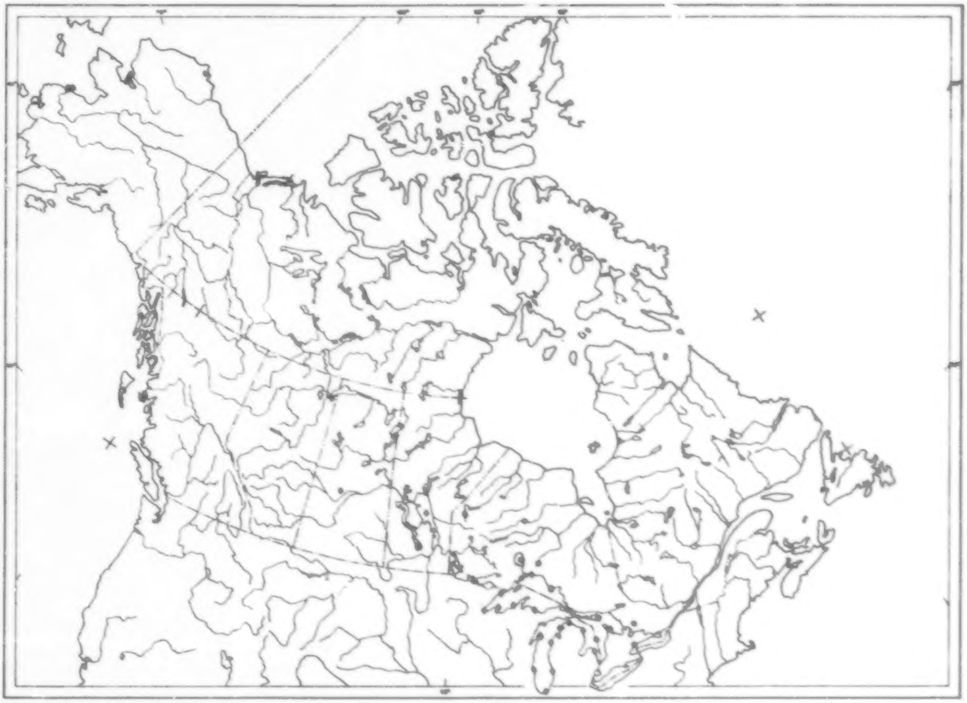
All Great Lakes populations, except those in Lake Nipigon, have become extinct, or nearly so, and hence, additional studies of the species will have to be conducted in inland waters. The validity of *nigripinnis* as a distinct species in many inland lakes is questionable. Even in Lake Huron, the similarity between *kiyi* and *nigripinnis* was so striking that Koelz (1929, p. 423) noted "small *nigripinnis* can be distinguished from *kiyi* probably only by the usual absence of black on the ventrals and the lighter pigmentation of the other ventral fins and by the fewer gill rakers, which in the former are (40)46–50(52) and in the latter (34)36–40(44), with 24 per cent more than 39." In Lake Superior, *nigripinnis* was less pigmented and most specimens had immaculate pelvic fins. The range in gill raker counts for Lake Superior *kiyi* was 36–45, and for *nigripinnis* 36–48, suggesting that differentiation of small *nigripinnis* from *kiyi* must have been difficult indeed.

Although *kiyi* does not occur in inland waters, *Coregonus artedii* does and it is often difficult to distinguish *nigripinnis* from *artedii*. Koelz remarked upon the similarity of *artedii* and *nigripinnis* in Lake Superior and compared the two species in such characters as the numbers of gill rakers and lateral line scales, and a variety of body measurements. He demonstrated that the two species could be distinguished in Lake Superior with a high degree of reliability. However, the same characters that would separate the two species in Lake Superior showed much greater overlap in Lake Nipigon and were, thus, much less effective. Compare, for example, gill raker counts:

	L. Superior	L. Nipigon
C. artedii	38–53	41–53
C. nigripinnis	36–48	44–54

Most coregonine fishes caught in inland lakes in northern Ontario and elsewhere in northern Canada tend to have darker fins and to be darker overall than the same species in the Great Lakes. *Coregonus artedii* with dark fins from inland lakes might easily be identified as *nigripinnis*.

The suspicion that *artedii* populations in inland lakes may have been identified as *nigripinnis* received support recently in an investigation of the ciscoes of Lake Waskesiu, Sask., by Kooyman (1970). Both *nigripinnis* and *artedii* (= *tullibee*) were reported to occur in the lake (Dymond and Pritchard 1930; Dymond 1943) but on re-examination only one species group, *Coregonus artedii*,



could be identified, although there were two distinct spawning groups, which differed markedly in age composition.

Coregonus nigripinnis is a problem species in inland waters and is most decidedly in need of critical systematic review. It may well prove to be taxonomically inseparable from a broadly redefined *Coregonus artedii*.

Distribution The blackfin cisco once ranged through all the Great Lakes except Lake Erie, but has now entirely disappeared from lakes Ontario and Michigan and there are no recent records from lakes Huron or Superior. It has been reported from a number of inland lakes in Ontario and Manitoba. Dymond (1943) considered this species to occur also in such Saskatchewan lakes as Waskesiu, Little Trout, Burntwood, and Heart, and from Lake Athabasca in Alberta. However, its occurrence in Saskatchewan and Alberta has not been confirmed by recent studies (Kooyman 1970).

Biology Information on time and place of spawning of Great Lakes stocks is indefinite. In Lake Superior, Koelz (1929) reported that "Pearled males and females spent, spawning, or nearly ripe were collected out of Grand Marais, Mich., on October 3, 1917, in 65 fathoms and deeper (record 2) and out of Rossport, Ont., on October 4, 1921, in 80 to 90 fathoms." Conclusive decisions on time of spawning in the other Great Lakes cannot be made but the available evidence suggests that it took place late November to January, possibly over a clay bottom.

There appears to be no data available on fecundity, embryological development, or early life history.

No age and growth studies are available for Great Lakes stocks or for inland lakes in Ontario. Keleher (1952b) presented growth data for Lake Winnipeg blackfin ciscoes but experienced considerable difficulty distinguishing the various species of ciscoes in the lake; hence, some mixing of data is possible. His data is presented below:

Age (years)	SL (inches)	SL (mm)
2+	5.5	140
3+	5.4	138
4+	7.2	183
5+	8.9	225
6+	10.1	256
7+	11.3	287
8+	12.3	313
9+	12.3	313
10+	13.0	330
11+	13.0	330

In Lake Winnipeg, this species appeared to have a relatively rapid rate-of-growth, grew larger than any other cisco (attaining a maximum age of 11 years) and the available data there suggest that males matured at age 4 or 5, females at age 4. Maximum sizes are not known but Dymond (1926) gave a length of 15.3 inches (388 mm) for Lake Nipigon specimens. In the Great Lakes it was regarded as the largest of the deepwater ciscoes or chubs.

The blackfin was found mainly in the deep waters of large lakes, and in the Great Lakes was considered to inhabit deeper waters than most other species. In smaller inland lakes it lived in shallower water. It has been captured at depths of 600 feet (183 m) in lakes Huron and Superior and may have occurred at even greater depths. In Lake Nipigon, Dymond reported that it was taken at greater depths than any other species, to 340 feet (104 m), but in summer it occurred in numbers at depths of 120 feet (37 m).

The food in the stomachs of 56 individuals caught in Michigan waters of Lake Huron in September and October, 1917, and of 2 caught off Lion's Head, Georgian Bay, in October, 1919, was reported by Koelz (1929). *Mysis relicta* was almost the sole food, but one or two stomachs contained traces of plant fragments, insect remains, and a fish scale. All fish were caught at depths of more than 360 feet (110 m).

The blackfin cisco, along with the other deepwater ciscoes, formed the basic food of lake trout in the deep waters of Lake Superior and possibly also in Lake Huron and Lake Nipigon until the 1950's. Because of its relatively large size, for a cisco, it was also preyed upon by the sea lamprey (Moffett 1957). In inland lakes it is probably an important prey of larger predaceous fishes.

The cestode *Triaenophorus crassus* was present in the flesh of about 60% of the blackfin ciscoes from Lake Winnipeg examined by Keleher (1952b).

Relation to man The blackfin was a highly prized commercial species in the Great Lakes, especially in the smoked fish trade, but is no longer of commercial importance (*see* p. 230–231). It was usually caught in gillnets. It is still caught in inland lakes in Ontario and in Lake Winnipeg and elsewhere in Manitoba but is usually marketed under the general name tullibee.

Nomenclature

Argyrosomus nigripinnis — Gill (*in* Hoy 1872: 99) (type locality Lake Michigan off Racine)
Coregonus prognathus — Smith 1895: 4
Argyrosomus prognathus (H. M. Smith) — Evermann and Smith 1896: 314
Leucichthys prognathus (H. M. Smith) — Jordan and Evermann 1911: 23
Leucichthys nigripinnis (Gill) — Jordan and Evermann 1911: 26
— Dymond 1926: 62
— Dymond 1943: 218
Leucichthys cyanopterus Jordan and Evermann — Jordan and Evermann 1911: 27
Coregonus nigripinnis (Gill) — Hubbs and Lagler 1958: 55

Etymology *Coregonus* — angle-eye, coined by Artedi from the Greek words meaning pupil (of the eye) and angle; *nigripinnis* — *niger* — black, *pinna* — fin.

Common names Blackfin cisco, blackfin, black-fin tullibee, black-back tullibee, blackfin, mooneye cisco, bluefin. French common name: *cisco à nageoires noires.*

SHORTNOSE CISCO

Coregonus reighardi (Koelz)

Description Body elongate, average length to about 10 inches (254 mm), slightly compressed laterally but less so than other ciscoes; approaching the cylindrical form in cross section, greatest body depth in front of dorsal fin, 22–27% of total length. Head short, stout, 20–23% of total length; eye small, smaller than most species, 22.2–26.4% of head length; snout short, truncate in side view because of near vertical position of premaxillaries; mouth small, terminal, lower jaw included in upper jaw, not protruding beyond upper, maxillary extending posteriorly to below anterior half of eye. Gill rakers full range, total count 32–42, but 32–38 (Lake Ontario), 34–38 (Lake Nipigon), 32–42 (Lake Superior). Branchiostegal rays 8–10 (Lake Superior). Fins: all fins rather short; small dorsal adipose present, dorsal 1, rays 8–11, usually 9–11; caudal distinctly forked; anal rays 9–13, usually 10 or 11; pelvic rays 10–12; pectoral rays 15–17. Scales cycloid, large, 68–78 (Lake Ontario), 65–83 (Lake Superior), 64–77 (Lake Nipigon), in lateral line. Vertebrae 55–58.

Nuptial tubercles are developed on males and on at least some females.

(*See also* Koelz 1924, 1929; Dymond 1926; Pritchard 1931.)

Colour Overall colouration silvery; silvery iridescence on sides, white below. The back of Lake Ontario specimens was described by Pritchard (1931) as light greenish straw-coloured; he also remarked that none of the other species of cisco showed the typical yellow-green straw colour of *reighardi*. Premaxillaries heavily pigmented, maxillaries pigmented on cutting edge and lower jaw pigmented. Dorsal and caudal fins pigmented, but others usually immaculate.

Systematic notes This species was described by Koelz (1924). The holotype is a female with large eggs in the body cavity, 8.3 inches (210 mm) in standard length, caught in Lake Michigan April 1, 1921, at a depth of 180–210 feet (54.9–64.0 m). It is stored in the United States National Museum, cat. no. 87351, and was in excellent condition when examined in 1959. Koelz (1929) considered the populations in lakes Superior and Nipigon to differ significantly from those in lakes Ontario and Michigan. The typical subspecies *C. reighardi reighardi* was said to inhabit lakes Ontario and Michigan, while *C. reighardi dymondi* lakes Nipigon and Superior. The Nipigon form was considered to have fewer scales, more dorsal and anal rays, and a relatively longer head, maxillary, and pectoral fins.

Distribution The shortnose cisco was indigenous to the Great Lakes basin and was limited in distribution to lakes Ontario, Huron, Michigan, Superior, and Nipigon. Lake Huron specimens were unknown until 1956 (Scott and Smith 1962).

Biology Spawning occurred in western lake Ontario, mainly during April and the first two weeks of May, in about 250 feet (75 m) of water, according to Pritchard (1931). He noted he had been unable to determine when spawning ended, but a few ripe fish were found as late as the first week of June. A spent female was caught as early as January 26, but premature ripening of occasional individuals was not uncommon among the deepwater ciscoes. Captures by commercial fishermen suggested that spawning may have taken place somewhat later in eastern Lake Ontario.

In Lake Michigan spawning occurred chiefly in May and June at depths of 120–470 feet (36.6–144.5 m) at temperatures of 38.8°–40.5° F (3.8°–4.7° C), over sand, silt, silt and clay, or clay bottoms, according to Jobes (1943).

In the remaining Great Lakes (Michigan, Superior, and Nipigon) the shortnose cisco also spawned in spring, although the evidence available to Koelz (1929) led him to believe that spawning occurred in November.

In recent years changes in spawning behaviour have been noted. Smith (1964a) remarked upon the presence of large numbers of *C. reighardi* in spawning condition, in the fall, in an area in Lake Michigan where they spawned the previous spring. It was suggested that such a change might well increase the probability of hybridization with a fall-spawning species.

Information on fecundity, embryological development and early life history was apparently never published.

Ages can be determined from the scales and age analyses indicated that growth was relatively slow. Lengths and weights at ages 1–8, for lakes Ontario (Pritchard 1931) and Michigan (Jobes 1943) are given in the table below.

Females outlived males by about 2 years in Lake Michigan, where they attained age 8+ according to Jobes (1943). The oldest shortnose cisco reported by Pritchard (1931) for Lake Ontario was also 8+, and was probably a female. In Lake Ontario they grew at least to 14 inches (356 mm) long and 19 ounces (539 g) in weight.

In the Canadian waters of Lake Ontario, the shortnose cisco occurred at depths of 75–300 feet (22.9–91.4 m). Few were taken at depths of less than 75 feet and maximum numbers occurred at 250 feet (76.8 m). In Lake Nipigon, maximum numbers occurred at 90–100 feet (27.4–30.5 m).

The stomach contents of 27 specimens from Lake Ontario were examined by Pritchard. *Mysis relicta* and *Pontoporeia hoyi* were the major food items but small numbers of copepods, aquatic insect larvae, and fingernail clams were also eaten.

The following information on parasites applies to the former Lake Ontario population (Pritchard 1931). The copepod, *Salmincola inermis* occurred in 5% of specimens examined, the nematode *Cystidicola* in 45%, and an acanthocephalan, *Echinorhynchus* sp., in 45%. The latter parasite was not observed in any other cisco in Lake Ontario.

Relation to man This was once a valuable commercial species in Lake Ontario until at least the 1940's. Pritchard considered it one of the most important and valuable ciscoes taken in Canadian waters and Stone (1947) remarked that small catches were made in New York waters in the spring. Although *reighardi* was a rather small fish, averaging about one pound or less, it was very fat and considered excellent for smoking. It has become exceedingly rare in recent years in Canadian and United States waters of Lake Ontario. Wells (1969) reported two specimens caught in experimental fishing in United States waters during 1964–1966, and Christie (personal communication 1970) stated that only a few specimens had been seen in recent years.

It was also one of the important deepwater ciscoes in the "chub" fishery of lakes Michigan and Superior but it has largely disappeared from Lake Michigan and has been greatly reduced in numbers in Lake Superior. Its status in Lake Nipigon is unknown. For further information on this species in relation to the chub fishery, *see* p. 230–232.

		Age (*years*)							
		1+	2+	3+	4+	5+	6+	7+	8+
	FL								
L. Ontario	*inches*	7.3	–	9.7	9.9	10.6	10.0	11.4	11.1
	mm	185	–	246	251	269	254	290	282
	Wt (*oz*)	1.8	–	6.8	7.8	9.1	7.1	12.6	14.8
	TL								
L. Michigan	*inches*	–	10.4	10.7	10.9	11.2	11.4	–	–
	mm	–	264	272	277	284	290	–	–
	Wt (*oz*)	–	5.7	6.1	6.1	6.6	7.1	–	–

Nomenclature

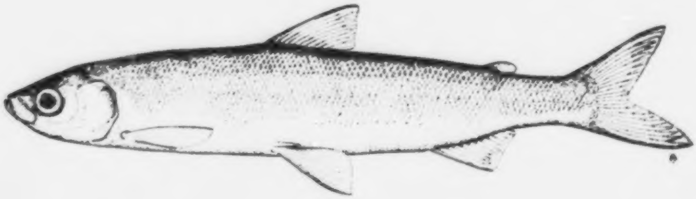
Leucichthys reighardi — Koelz 1924: 5 (type locality Lake Michigan, 18 miles NxW off Michigan City, Ind.)
Coregonus reighardi (Koelz) — Hubbs and Lagler 1958: 54

Etymology *Coregonus* — angle-eye, coined by Artedi from Greek words meaning pupil (of the eye) and angle; *reighardi* — in honour of Jacob Reighard, a well-known and respected ichthyologist, Department of Zoology, University of Michigan.

Common names Shortnose cisco, Reighard's chub, Reighard cisco, shortnose chub, greaser. French common name: *cisco à museau court*. The term "greaser" is from Stone (1947: 234) in reference to specimens from Lake Ontario, N.Y.

LEAST CISCO

Coregonus sardinella Valenciennes

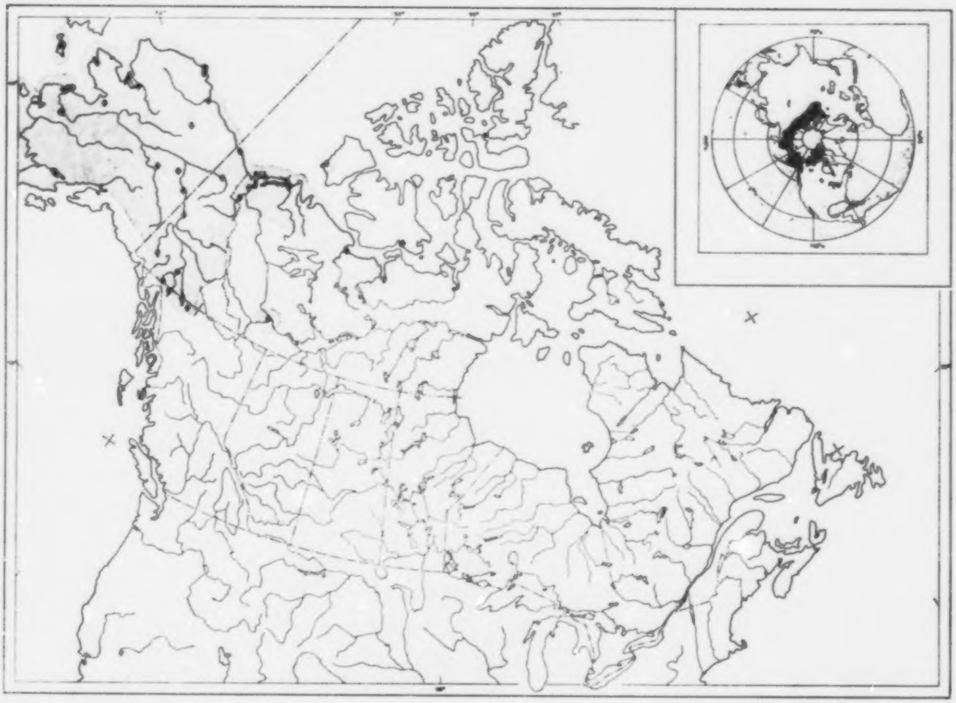


Description Body elongate, length to about 8–10 inches (203–254 mm), somewhat compressed laterally, greatest body depth at front of dorsal fin 19–24% of total length. Head about 19–24% of total length; eye large, its diameter 26–32%; snout length usually less than eye diameter; mouth moderate, terminal, lower jaw always protruding, maxillary at a distinct angle, extending posteriorly to below anterior half of eye; a small cluster of teeth on tongue. Gill rakers, total count 42–53. Branchiostegal rays 8 or 9. Fins: adipose dorsal present; dorsal 1, high, falcate, rays 12–14; caudal distinctly forked; anal rays 11–13; pelvic rays 8–12, a distinct pelvic axillary process present; pectorals narrow, pointed, rays 14–17. Scales cycloid, large, 78–98 in lateral line. Pyloric caeca 74–111. Vertebrae 58–64.

Nuptial tubercles presumably developed on scales on flanks of males.

This species occurs in both fresh water (nonmigratory) and marine (migratory) forms. The latter is often larger and heavier than the former, and there are other differences such as colour. *See also* McPhail and Lindsey (1970).

Colour Overall colouration silvery; usually brown to dark green on the back, becoming silvery on sides and below. The small non-anadromous form that remains in fresh water is without spotting on back and only the pelvic fins have black pigment on tips,



the remaining fins are unpigmented. The larger, anadromous form has dark spots on head, back, dorsal, and adipose fins and, sometimes, on pectoral fins; all fins usually have dark pigment on tips.

Systematic notes This species was described by Valenciennes (1848) based on specimens from the Irtysh and Kolyma rivers, Siberia. For many years northern North American populations were referred to *Coregonus pusillus* Bean, but Dymond (1943) noted the similarity of *pusillus* to *sardinella* and recommended that *pusillus* be regarded as a synonym. At present, North American populations are not distinguished taxonomically from those in Siberia, but in a recent treatment, McPhail and Lindsey reviewed the North American systematic history of the species, drawing particular attention to the existence of two forms or types: one that lives out its entire life in fresh water (nonmigratory) and another form that ascends rivers in summer from arctic seas and descends again in late autumn (migratory). The differences in size, colour, and morphometry emphasize the existence of two well-marked forms. The migratory form has a gill raker range of 48–53, mean about 50, while the freshwater form has a range of 41–47 with a mean near 45; some exceptional Alaskan populations were noted. These authors have called the least cisco populations *"Coregonus sardinella"* complex. Their account should be consulted for additional details.

Distribution The least cisco occurs in coastal waters and in certain inland lakes and rivers in northern Europe, Asia, and North America, from the White Sea region west to Alaska and the Northwest Territories.

In North America it occurs in many inland waters and most of coastal Alaska north of Bristol Bay, including the Arctic Ocean drainage. In Canada it occurs in many inland waters (Atlin, Teslin, and Swan lakes in extreme northern British Columbia and Yukon Territory, the Mackenzie, Peel and lower reaches of many arctic rivers) and in arctic coastal waters east at least to Bathurst Inlet; north to Victoria and Banks islands.

Biology The biology of the least cisco has been little studied in Canada and, hence, little direct information is available; but many studies have been made on Siberian populations and some work has been done in Alaska. Much of this information has been summarized by Nikol'skii (1954) and by McPhail and Lindsey (1970).

The biology of the least cisco is somewhat complicated by the existence of migratory and nonmigratory populations. Spawning occurs in autumn, usually in September or October in Siberia. The eggs are deposited over sand or gravel in shallows of rivers or along lake shores, and abandoned by the spawners, as is usual among whitefishes. In the Yenisei River, Siberia, females carry from 2500–23,600 eggs. The eggs remain over winter on the bottom, and hatch the following spring. In the USSR the larvae of the migratory forms, upon hatching, move downstream toward the sea.

Growth rates of migratory forms are usually greater than those of nonmigratory or freshwater forms, and migratory forms usually reach a greater maximum age. The oldest fish at Teslin Lake, B.C., and Yukon Territory (a freshwater population) was 8 years old, weighed 4 ounces (113 g), and was 9.8 inches (249 mm) long; the largest was 6 years old, weighed 11 ounces (312 g), and was 10.9 inches (276 mm) long. Studies by Cohen (1954) in Alaska indicated that migratory forms reached 11 years of age, freshwater populations only 9. In Siberia the maximum age attained was also 11 years (Nikol'skii). Some Canadian populations may attain much greater ages, for specimens from Victoria Island, N.W.T., attained ages approaching 26 years (J. G. Hunter, personal communication). Migratory forms may reach a length of 16.5 inches (419 mm), freshwater forms 9 inches (229 mm).

Throughout its coastal range the migratory form of the least cisco exhibits an upriver migration in spring and summer; following spawning in the autumn the populations again move downstream.

In Siberian waters, planktonic crustaceans are the main foods but river populations apparently feed also on aquatic and terrestrial insects.

It is said to be eaten by lake trout, inconnu, northern pike, and burbot in Atlin and Teslin lakes in northern British Columbia (Carl et al. 1967).

Studies of the mortality rates of this species in Ikroavik Lake, Alaska, indicated that only 5% of all sizes were noticeably parasitized but the parasites involved were not identified (Wohlschlag 1954a, b). Parasites of this species in waters of the USSR, as compiled by Bykovskaya-Pavlovskaya et al. were listed by Lawler (1970).

Relation to man The least cisco is not considered to be of much commercial importance in North America because of its small size and slow growth rate (Dymond 1943; Cohen 1954), but it constitutes one of the most important commercial fishes in the lower reaches of Siberian rivers. It is caught incidentally in the Mackenzie River (and possibly others) in gillnets set for other whitefishes. Wynne-Edwards (1952) noted that it was caught with a hook by children at Carcross, southern Yukon Territory, where it occurred in large numbers in summer. Although it is of small size, the flesh is said to have an excellent flavour.

Nomenclature

Coregonus sardinella	— Valenciennes 1848 (*in* Cuvier and Valenciennes 1828–49) (type locality Irtysh and Kolyma rivers, Siberia)
Coregonus pusillus	— Bean 1889: 526
Argyrosomus pusillus (Bean)	— Jordan and Evermann 1896–1900: 470
Leucichthys pusillus	— Dymond 1943: 204
Leucichthys sardinella (Valenciennes)	— Carl and Clemens 1948: 38

Etymology *Coregonus* — angle-eye, coined by Artedi from Greek words meaning pupil (of the eye), and angle; *sardinella* — small sardine.

Common names Least cisco, lake herring, cisco, big-eye Mackenzie herring. French common name: *cisco sardinelle*.

SHORTJAW CISCO

Coregonus zenithicus (Jordan and Evermann)

Description Body elongate, average length to about 11 inches (279 mm), more compressed laterally than most other deepwater ciscoes; greatest body depth in front of dorsal fin, 19–27% of total length. Head elongate but not deep, its length 22.8–27.0% of total length; eye moderate, its diameter 19.7–25.6% of head length; snout usually longer than eye diameter, its length 25.0–32.2% of head length; mouth moderate, terminal, lower jaw included in upper jaw or lower jaw protruding (latter more usual in inland populations), maxillary long, (hence the oft-used commercial name, "longjaw"), extending to middle of eye or slightly beyond. Gill rakers, full range total count 32–46, but 34–44 in Lake Huron, 32–46 in Lake Superior, 33–42 in Lake Nipigon, 34–40 in lakes Winnipeg and Athabasca. Branchiostegal rays 8–10. Fins: small adipose dorsal present; dorsal 1, rays 9–11, usually 10 or 11; caudal distinctly forked; anal rays 10–13, usually 11 or 12; pelvic rays 11 or 12, a distinct pelvic axillary process present; pectoral rays 15–18, usually 16 or 17. Scales cycloid, large, lateral line with 70–88 in Lake Huron, 69–90 in Lake Superior, 66–83 in Lake Nipigon, 58–69 in lakes Winnipeg and Athabasca. Vertebrae 54–58 (Lake Nipigon).

Nuptial tubercles developed on males.

(*See also* Dymond 1926; Koelz 1929; Dymond and Pritchard 1930.)

Colour Overall colouration silvery; usually greenish on back, becoming silvery on sides, with purplish iridescence, and white below. Pelvic and anal fins usually immaculate or only lightly pigmented, pectorals lightly pigmented, but dorsal and caudal fins sometimes darkly pigmented.

Systematic notes This species was described by Jordan and Evermann (1909). The holotype is a male, 278 mm standard length, 12.0 inches (305 mm) fork length, caught by John Coventry in Lake Superior in September 1908, off Isle Royale. It is stored in the United States National Museum, cat. no. 62517 and was in excellent condition when examined in 1959.

This is one of the problem ciscoes, taxonomically speaking, for, although it was rather readily recognizable in the Great Lakes, reports of its occurrence elsewhere in Canada have often been viewed with lingering doubts. Dymond and Pritchard (1930) reported *zenithicus* from Lake Winnipeg, Man., and from Lake Athabasca, Alta., Dymond (1943) included Reindeer Lake, Sask., in the range, and also the Northwest

Territories, the latter based on descriptions of new species by Harper and Nichols (1919) (*Leucichthys athabascae*, *L. entomophagus* and *L. macrognathus*) which he (Dymond) considered to be synonyms of *zenithicus*.

In a discussion of *"Coregonus artedii"* complex in northwestern Canada, McPhail and Lindsey (1970) questioned Dymond's decision concerning *athabascae*, *entomophagus*, and *macrognathus*, indicating that, upon a restudy of the holotypes, that were stored in the National Museum of Canada, ". . . Dymond's (gill raker) counts are consistently low" and that the revised gill raker counts were, *athabascae* 40+ (damaged), *entomophagus* 37, and *macrognathus* 42, instead of 35, 35, and 37, respectively, as reported by Dymond. Therefore, only *entomophagus* could be considered a synonym since gill rakers of the other two fell within the range of *artedii*. In all fairness, however, it should be pointed out that Dymond (1943, p. 216) explained in a footnote that the count of 35 for *athabascae* was taken from Harper and Nichol's own account, and was not a count that he made personally. McPhail and Lindsey's discussion of *zenithicus*, however, implied a dependency on gill raker counts alone as a means of identifying the species, and, in our experience, *zenithicus* may have gill raker counts up to 46. For example, in Lake Superior, the type locality, *C. zenithicus* has a gill raker range of 32–46.

White Partridge Lake, in the vicinity of Algonquin Park, Ont., and a few other glacial lakes in the area, have populations of ciscoes that mature at lengths under 4 inches (100 mm), have gill raker counts of 38–42, and head and body measurements that are typical of *zenithicus*. It is expected that many more populations of such small ciscoes will be found in other parts of the country. We have also examined specimens from Alberta (Paterson 1969) which conformed to the classical description of *zenithicus*, but which were of large size.

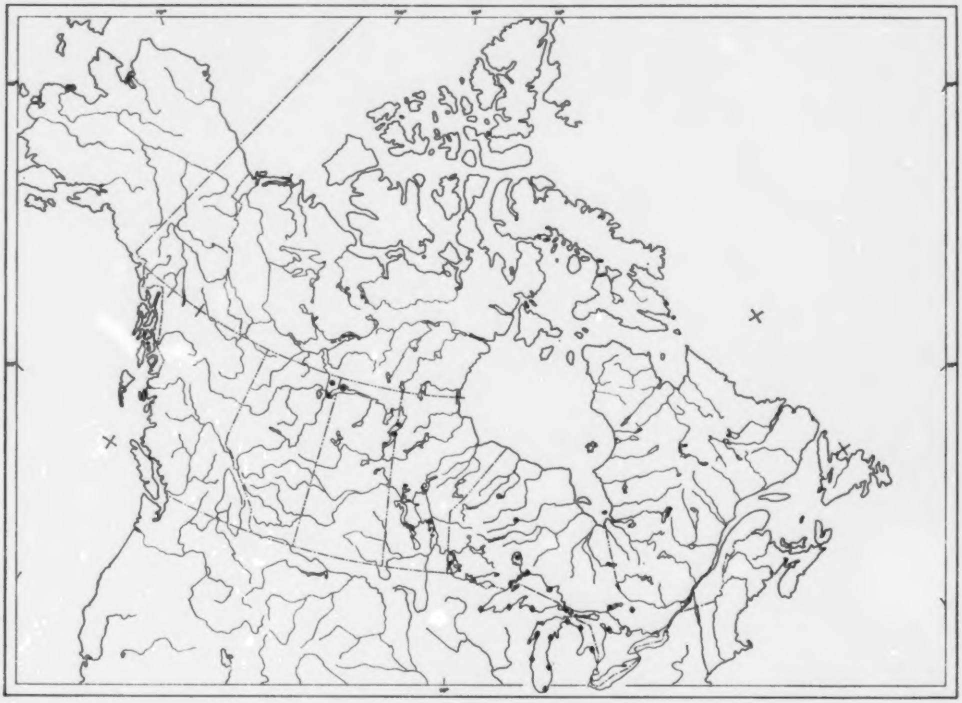
The species identified as *zenithicus* in Lake Winnipeg (re-examined by Keleher (1952b)) was recognized primarily by means of gill raker counts but was not readily distinguishable by other features (although Keleher's differential correlations of *Triaenophorus* parasitism with different species of ciscoes are of considerable interest). These and other observations clearly indicate that the verification of the presence of *Coregonus zenithicus* in waters other than the Great Lakes must await considerably more investigation of the subgenus *Leucichthys* in Canadian lakes than has been attempted heretofore.

Distribution The complete range of the shortjaw cisco is not fully known. In the Great Lakes basin, it was formerly caught in lakes Huron, Michigan (probably extirpated), Superior, and Nipigon. North and west, fish described as this species have been reported from Lake Winnipeg, Man., Reindeer Lake, Lake Athabasca, Sask., Barrow Lake, Alta., by Paterson (1969), and Great Slave Lake, N.W.T. Dwarf specimens have also been reported from inland lakes in and around Algonquin Park, Ont. There are indications that small or dwarf *zenithicus*, which mature at lengths of less than 5 inches (127 mm), may be more widely distributed in inland lakes than was previously thought.

Biology Spawning takes place in the fall but the time apparently varies from lake to lake. In Lake Huron observations by Koelz (1929) suggested that spawning occurred between September 28 and October 14, 1917, while in Lake Nipigon spawning was thought to occur about the first part of November. In Lake Superior, studies by Koelz (1929) and Van Oosten (1937a) indicated that spawning occurred in late November or early December, probably at a depth of 120–240 feet (37–73 m), over a clay bottom.

Information on fecundity, embryological development, and early life history have not, apparently, been published.

Age can be determined by scale analysis. A study of *zenithicus* from Lake Superior by Van Oosten (1937a) from specimens collected in 1922, suggested that growth was rapid in the first year, and slower in subsequent years. Gain in weight was slow during the first four years but during the fifth and sixth years a rapid increase in weight



occurred (53% in males and 66% in females). It was suggested that the species be protected until at least its sixth year, when it reached a total length of about 10.3 inches (262 mm). Males and females grew at about the same rate but females tended to be heavier than males at corresponding lengths and ages, and females also lived longer and, hence, reached a larger size than males. The largest male reported by Van Oosten from Lake Superior was 13.8 inches (351 mm) long and weighed 9.7 ounces (276 g), the largest female, 14.5 inches (368 mm) long, weighed 10.3 ounces (292 g). Lengths and weights of *zenithicus* from Lake Winnipeg and Lake Superior are given in the table below.

This is a deepwater species that ranges in depth from about 60–600 feet (18–183 m) in the Great Lakes. In Lake Superior, Dryer (1966) observed seasonal depth distribution of 360–414 feet (110–144 m) in spring, 180–234 feet (55–71 m) in summer, and 240–294 feet (73–90 m) in winter. Throughout the seasons it was most common at 180–414 feet (55–144 m). In inland waters in

		Age (*years*)								
		2+	3+	4+	5+	6+	7+	8+	9+	10+
	TL									
L. Superior	*inches*	–	–	9.2	10.9	11.7	12.3	12.8	13.8	13.6
(Van Oosten	*mm*	–	–	234	277	297	312	325	351	345
1937a)	Wt (*oz*)	–	–	2.7	4.4	5.3	6.0	7.0	8.8	8.8
	SL									
L. Winnipeg	*inches*	5.4	5.3	7.2	8.7	9.4	9.8	10.1	10.9	–
(Keleher 1950)	*mm*	138	135	182	221	240	250	258	277	–

Ontario it has been captured in glacial lakes of 100–150 feet (30.5–45.7 m) in depth in which *Mysis relicta* and *Percopsis omiscomaycus* were also found (Martin and Chapman 1965).

In the Great Lakes the primary food items appear to have been *Pontoporeia hoyi* and *Mysis relicta* but planktonic Crustacea and aquatic insect larvae were also found in stomachs. Bajkov (1930) reported similar food eaten by Lake Winnipeg specimens.

The shortjaw cisco formed a part of the natural diet of the lake trout and burbot in the Great Lakes, and, following the arrival of the sea lamprey, the shortjaw was probably preyed upon directly by it as well. Small, dwarfed ciscoes, presumed to be this species, are commonly observed in stomachs of lake trout caught in glacial lakes in the vicinity of Algonquin Park, Ont.

Keleher (1952b) reported a fairly high degree of infection of Lake Winnipeg *zenithicus* by *Triaenophorus crassus*, but could find no correlation between degree of infection and age.

Dead *zenithicus* found on shores of White Partridge Lake, Algonquin Park, Ont., had large numbers of a species of *Diphyllobothrium* blocking heart vessels; the parasites were considered numerous enough to have caused death (R. S. Freeman, personal communication).

Hoffman (1967) listed the cestodes *Cyathocephalus truncatus* and *Proteocephalus laruei*, parasites of this species in North American fresh waters.

Relation to man This species was once considered of importance in the Great Lakes "chub" fishery (*see* p. 231) of lakes Michigan and Huron. It no longer exists in Lake Michigan and its status in Lake Huron is unknown. It is probably one of the more common ciscoes in Lake Superior but its importance there and in Lake Nipigon is not known. In 1937, Van Oosten wrote that it was the only large chub that was common enough to be taken in commercial quantities.

In Manitoba, *zenithicus* was formerly an important part of the "tullibee" fishery and was mainly exported to the United States for the smoked fish market.

Nomenclature

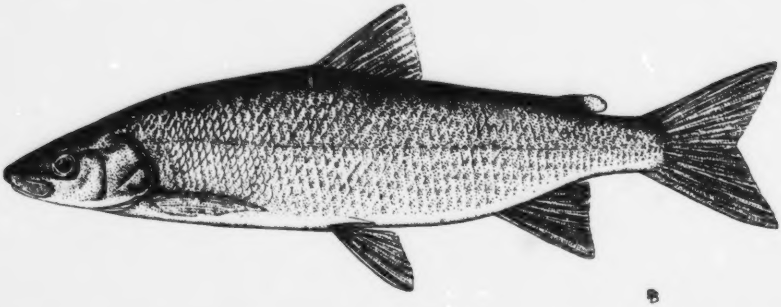
Argyrosomus zenithicus	— Jordan and Evermann 1909: 169 (type locality deep water off Isle Royale, L. Superior — between Duluth and Isle Royale)
Leucichthys entomophagus	— Harper and Nichols 1919: 267
Leucichthys athabascae (?)	— Harper and Nichols 1919: 269
Leucichthys macrognathus (?)	— Harper and Nichols 1919: 269
Leucichthys zenithicus (Jordan and Evermann)	— Dymond 1926: 65
	— Dymond 1943: 215
Coregonus zenithicus (Jordan and Evermann)	— Hubbs and Lagler 1958: 54

Etymology *Coregonus* — angle-eye, coined by Artedi from Greek words meaning pupil (of the eye), and angle; *zenithicus* — named after Duluth, "the Zenith City," where "Hundreds of specimens of this species were seen in the cold-storage plant of Booth and Company."

Common names Shortjaw cisco, shortjaw chub, longjaw, light-back tullibee, paleback tullibee, short-jaw chub, Lake Superior longjaw. French common name: ***cisco à mâchoires égales.***

LAKE WHITEFISH

Coregonus clupeaformis (Mitchill)



Description Body elongate, average length to about 15 inches (381 mm), small fish usually slender but large fish may be somewhat ovate in lateral view, compressed laterally, greatest body depth at front of dorsal fin but depth variable, greater in mature females than males and increasing with increase in weight, but usually 23–33% of total length. Head short, 20–23% of total length, large, old fish may develop a hump behind head, (nuchal hump) also common on fish from northwestern Canada; eye small, its diameter 19.5–25.0% of head length; snout projecting beyond mouth, its length 27–35% of head length; mouth inferior, distinctly overhung by snout, maxillary extending posteriorly to about the anterior edge of the pupil, maxillary length 22–28% of head length; 6–8 small, weak teeth present on premaxilla to 30–40 mm stage, and an occasional tooth at lengths to 84 mm, teeth also on dentary at lengths to 80 mm but absent on adults, weak teeth also on lingual plate. Gill rakers, extreme range 19–33, seldom fewer than 22 in eastern Canada; length of longest gill raker 22–44% of interorbital width. Branchiostegal rays 8–10. Fins: dorsal adipose present; dorsal 1, rays 11–13; caudal distinctly forked; anal rays 10–14; pelvic rays usually 11, sometimes 12, pelvic axillary process present; pectoral rays 14–17. Scales cycloid, large, extreme range 70–97 in lateral line, a heavy overlay of mucus or slime overlays the scales and causes whitefish to feel more slimy than ciscoes. Pyloric caeca 140–222. Vertebrae 55–64 (range in Lake Opeongo, Algonquin Park, Ont., 55–63).

Nuptial tubercles or pearl organs developed on scales on flanks of breeding males, smaller and fewer on females; on males they are well developed on at least 3 rows of scales above the lateral line and on 6 rows below.

(*See also* Koelz 1929, 1931; McPhail and Lindsey 1970.)

Colour Overall colouration silvery; back pale greenish brown (Great Lakes) or light brown and sometimes dark brown to almost black (inland lakes), becoming silvery on the sides and silvery white below. In northwestern Canada, lake whitefish exhibit darkened scale margins, lending a darker colour than that of eastern fish on which the scale pattern is lacking or only weakly developed. The fins are usually clear or only lightly pigmented in the Great Lakes but farther north the fins are often darker and are usually black tipped.

Systematic notes The lake whitefish was described by Mitchill in 1818, as *Salmo clupeaformis* from St. Mary's River below the falls, at the northern extremity of Lake Huron. The holotype does not exist and as Koelz (1929) indicated, Mitchill's description was inadequate.

Coregonus clupeaformis has presented a confused taxonomic picture, particularly in northwestern North America where, in addition to the existence of Eurasian forms such as *C. nasus* and possibly also *C. pidschian*, inadequate and poorly preserved specimens were available for study. As an example of this confusion, *C. clupeaformis* was equated or synonymized with three different Eurasian species by three different authors (Walters 1955; Svärdson 1957; and Gasowska 1960). Considerable clarification was achieved when the distinctness of *clupeaformis* from *nasus* was ably demonstrated by Lindsey (1962) but many problems remain. In various parts of North America there exist sympatric pairs of whitefish species that differ significantly in growth rate, size at maturity, and other features, but usually are not distinguishable by the usual morphometric and meristic characters, such as gill rakers. Such populations are usually referred to as "dwarf" and "normal" whitefish and have been shown to occur in Algonquin Park, Ont., (Kennedy 1943), Maine (Fenderson 1964) and possibly Lake Superior (Edsall 1960). Other similar sympatric populations are known to exist. Such a case was noted for Lake Simcoe by MacCrimmon and Skobe (1970), and McPhail and Lindsey (1970) mentioned others. Even so, eastern North American populations seem less complex than those in the northwest. McPhail and Lindsey found it expedient to refer to the North American lake whitefishes as "*Coregonus clupeaformis*" complex, in recognition of the systematic problems existing in the northwest. *Coregonus nelsoni* Bean was included in the complex, but *see* Lindsey (1962, 1963). They provided an excellent review which should be consulted.

The investigation of protein characters, using electrophoretic techniques, offers attractive alternatives to traditional systematic methods. Some of these methods have been applied to *C. clupeaformis* by Lindsey et al. (1970). Cytogenetic parameters have also been applied by Booke (1968), who provided karotypes of this and other coregonine species.

In the Great Lakes, particularly in Lake Erie, hybrids between *C. clupeaformis* and *C. artedii* were well known as "mules" or "mule whitefish." They were remarkably bright green in colour but the shape of the mouth and the gill raker counts were intermediate between those for the parental species. The hybrids also exhibited very accelerated growth rates and attained weights of 2.5–3.0 pounds (1134–1361 g) at 2 years of age and one weighed 6.7 pounds at age 5. A "mule" weighing nearly 12 pounds (5.4 kg) was noted by Koelz (1929) but no age was given.

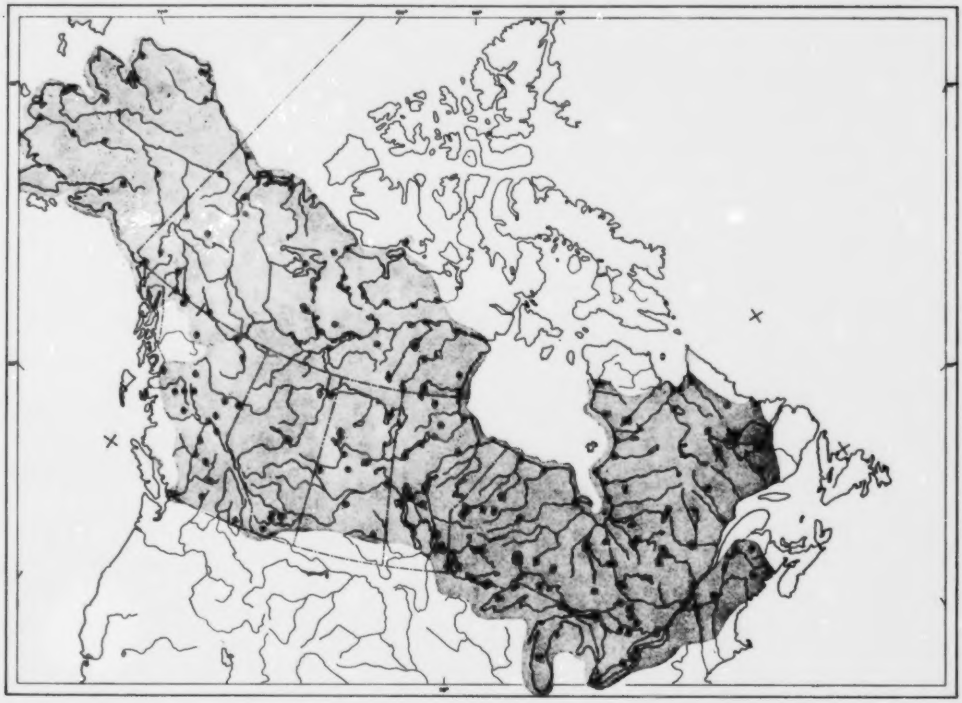
Distribution The lake whitefish is widely distributed in North American fresh waters from the Atlantic coastal watersheds westward across Canada and the northern United States, to British Columbia, the Yukon Territory, and Alaska.

In Canada, it occurs from New Brunswick and Labrador west throughout Quebec, including Ungava, throughout Ontario including the Great Lakes, to coastal waters of Hudson Bay, throughout Manitoba and in suitable waters of Saskatchewan (especially in the north), Alberta, and British Columbia, and is generally distributed throughout the Territories, in most large lakes and larger rivers. In Ungava, the Hudson Bay region, and Arctic Ocean drainages in the Northwest Territories it enters brackish water. The northern limit of range in Canada is near Cambridge Bay, Victoria Island, N.W.T.

It has been introduced into many parts of Canada (British Columbia, insular Newfoundland, Alberta) as a forage fish or in hopes of establishing commercial fisheries.

(*See* Dymond 1936; Cuerrier and Schultz 1957; Scott and Crossman 1964; Carl et al. 1967.)

Biology The biology of the lake whitefish has received considerable study, mainly because it has long been an important commercial species. Nevertheless, many aspects of its natural history have remained obscure, in particular, the movements and habits of young-of-the-year, which only recently have received much needed attention (Faber 1970; Reckahn 1970).



Spawning occurs in the fall, usually November and December in the Great Lakes region and generally earlier farther north but the exact date of spawning varies from year to year, even in the same lake. In Heming Lake, Man., spawning occurred mainly between October 19 and 25, 1953 (Lawler 1965a). In Great Slave Lake, spawning occurred from late September to October (Rawson 1947). In Lake Erie, Lawler (1965a) concluded that spawning was generally delayed until the temperature dropped to approximately 46° F (7.8° C) and that the spawning peak occurred at a lower temperature. In extreme northern waters, available evidence suggests that individuals may spawn only every second or third year.

Spawning usually occurs in shallow water at depths of less than 25 feet (7.6 m), but spawning in deeper water has been reported by Koelz (1929). It often takes place over a hard or stoney bottom but sometimes over sand. The number of eggs deposited by a female varies from population to population and tends to increase with size of female. The number of eggs per pound of fish has been calculated to be 16,100 for Lake Erie (Lawler 1961), (possibly high since counting was done in August on "green" eggs), 9900 for Lake Ontario (Christie 1963), and 8200 for Lake Huron (Cucin and Regier 1965). For a discussion of egg number and spawning potential *see* Christie (1963) and Cucin and Regier (1965). Female whitefish in Lake Erie have been calculated to lose approximately 11% of their weight at spawning (Van Oosten 1939). On extrusion, eggs measure about 2.3 mm in diameter but after 24 hours in water the size increases to 3.0–3.2 mm (Hart 1930).

The eggs are deposited more or less randomly over the spawning grounds by the parents. Observations of Lake Ontario stocks by Hart (1930) supported the view that spawning fish are active and may jump and thrash about, especially at night. Leaping completely out of the water by spawning whitefish was observed and reported to us by the late Dr A. E. Allin. The eggs remain on the spawning ground until they hatch in April or May.

The embryology and rate of development of whitefish eggs are well known because of fish hatchery work. The collection of whitefish eggs from spawning fish, their retention and incubation in hatcheries, and the subsequent release of eyed eggs and larvae in spring has been practiced since the last century (*see* section on *Relation to man*). For detailed information on egg and larval development, *see* Hart (1930) and Fish (1932); for information on the effects of temperature on egg development *see* Price (1940) and Lawler (1965a).

Under experimental conditions, normal development occurs over a temperature range of 33°–43° F (0.5°–6.1° C), with the optimum temperature close to 33° F (Price 1940). Mortalities and abnormalities increase with higher temperatures until eggs incubated at 50° F (10° C) suffer 99% mortality. The ecology of newly hatched whitefish, in nature, received little attention, except for the work by Hart (1930), until the recent work by Faber (1970) and Reckahn (1970). They noted that the larvae formed aggregations along steep shorelines and were associated at this time with larvae of burbot, cisco (*C. artedii*), the deepwater sculpin, and smelt. Young whitefish generally leave the shallow inshore waters by early summer and move into deeper water.

Like most coregonines, age can be determined by scale examination. An abundant literature on the subject exists, but *see* Hogman (1968) for a recent review.

The rate of growth of lake whitefish varies from lake to lake, but in general is relatively rapid. The generally accepted commercial size of 2 pounds (0.9 kg) is reached at different ages in different lakes but the age at which this size is reached ranges from an exceptional age 3 (Lake Erie) to age 4 in Lake Winnipeg, age 9 in Great Slave Lake, N.W.T., and age 10 at Lac la Ronge, Sask. In Lake Simcoe, the common lake whitefish attains weights of about 0.75–1.25 pounds (340–567 g) at ages of 6–9 years, but there are some faster-growing whitefish that attain a weight of 1 pound (454 g) at age 3 or 4 (MacCrimmon and Skobe 1970).

In all populations, males usually mature at a younger age than females and die earlier.

Growth rates for a number of Canadian populations are shown in the table, p. 273.

The existence of dwarf whitefish has been reported by Kennedy (1943), Fenderson (1964), and Edsall (1960). The table on p. 274 shows the growth rate (age–length relation) of dwarf whitefish, *Coregonus clupeaformis*, and of normal sympatric whitefish populations.

Lake whitefish attained sizes to 20 pounds or more in the Great Lakes 50 or more years ago. The maximum size is probably one reported by Van Oosten (1946) that weighed 42 pounds and was caught off Isle Royale, Lake Superior, about 1918. A whitefish weighing 24 pounds was reportedly caught in Lake Winnipeg in 1923–1924 (Keleher 1961). In Great Slave Lake, a lake whitefish, aged 28 years and weighing 12.75 pounds, (5.8 kg) was recorded by Kennedy (1953b) and seems to be about the oldest recorded. Almost as old were the fish reported by Hart (1931) from Shakespeare Island Lake that lived to age 27. The heaviest whitefish from Great Slave Lake was reported by Keleher (1961) to weigh 22 pounds (10 kg).

The lake whitefish is a cool water species, as indicated by temperatures required for successful incubation of its eggs. Over most of the southern part of its range it descends into the cooler waters of the hypolimnion during summer months. Such movement may be unnecessary in northern lakes lacking critical thermal stratification. Throughout most of the Great Lakes, these fish move from deep to shoal waters in early spring and back to deeper water as warming occurs. In the fall, of course, whitefish move into shallow water to spawn. In Lake Superior, Dryer (1966) reported no whitefish below 240 feet (73 m) and gave an all-season depth distribution of 60–174 feet (18–53 m), but Koelz (1929) noted that whitefish were caught during summer to depths of 420 feet (128 m).

		Age (*years*)																
		1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+
Eastern L. Ontario and Bay of Quinte (Christie 1963)	FL																	
	inches	–	–	15.7	16.7	16.9	17.0	17.5	18.2	18.5	20.0	–	–	–	–	–	–	–
	mm	–	–	399	424	429	432	445	462	470	508	–	–	–	–	–	–	–
L. Erie (Van Oosten and Hile 1949)	TL																	
	inches	12.0	14.5	17.5	18.7	20.0	21.0	22.0	23.3	23.3	23.5	23.8	24.7	25.0	25.2	–	26.6	–
	mm	305	368	445	475	508	533	559	592	592	597	605	627	635	640	–	676	–
	Wt (*lb*)	0.56	1.1	2.0	2.5	3.0	3.6	4.1	5.4	5.0	4.9	5.4	6.2	6.9	6.9	–	8.8	–
Southern Georgian Bay, L. Huron (Cucin and Regier 1965)	FL																	
	inches	–	–	17.0	18.1	19.2	20.2	21.2	21.8	23.0	–	–	–	–	–	–	–	–
	mm	–	–	432	460	488	513	538	554	584	–	–	–	–	–	–	–	–
L. Superior, U.S. shore (Dryer 1963)	TL																	
	inches	9.1	14.0	16.4	18.2	18.8	19.1	18.4	18.5	20.8	24.5	–	–	–	–	–	–	–
	mm	231	356	417	462	478	486	467	470	528	622	–	–	–	–	–	–	–
	Wt (*lb*)	0.2	0.9	1.5	2.1	2.4	2.5	2.2	2.2	3.2	5.6	–	–	–	–	–	–	–
L. Winnipeg, Man. (Kennedy 1954a)	Wt (*lb*)	–	–	1.7	2.1	2.4	2.6	2.8	3.0	3.4	3.6	4.0	4.3	6.1	6.3	8.0	–	8.3
Lac la Ronge, Sask. (Qadri 1968)	FL																	
	inches	–	7.0	8.5	9.6	11.0	12.1	13.3	14.3	15.4	16.5	17.3	18.2	19.0	20.0	20.8	22.6	–
	mm	–	178	216	244	279	307	338	363	391	419	439	462	483	508	528	574	–
	Wt (*lb*)	–	.15	.24	.41	.6	.76	1.1	1.4	1.7	2.0	2.2	2.7	3.0	3.6	4.5	5.4	–
Great Slave L., N.W.T. (Kennedy 1953b)	Wt (*lb*)	–	–	–	–	–	–	–	1.5	2.0	2.2	2.4	2.7	2.9	3.1	3.3	3.5	3.7
Nueltin L., N.W.T. (Kennedy 1963)	Wt (*lb*)	–	–	–	–	–	–	–	1.7	3.1	3.7	3.9	4.2	4.4	5.2	4.6	5.3	–

Tagging studies in Lake Huron and Georgian Bay, (Budd 1957b) indicated a general tendency for the fish to move in definite directions although no well-defined routes were observed. Fish tagged in South Bay in the spring tended to return the following spring. One whitefish was recaptured in southern Lake Huron, 150 miles from where it was tagged.

Whitefish are usually regarded as schooling fishes, although Faber (1970) did not consider the aggregations of larvae to fall within accepted definitions of schooling (Keenleyside 1955).

Adult lake whitefish are bottom feeders over most of the range, consuming a wide variety of bottom-living invertebrates and small fishes. In some regions, however, planktonic creatures form a large part of the diet, and even terrestrial insects may be taken at the surface (Clemens et al. 1923). Relationship between the number and length of gill rakers, and the types of food consumed has been noted by McPhail and Lindsey and was investigated by Kliewer (1970), who found gill raker length correlated with food type to such a degree that fish with short rakers and high gill raker counts ate a higher proportion of benthic food.

In a recent study of young whitefish in Lake Huron, Reckahn (1970) noted that copepods, especially *Diaptomus*, were important initially, cladocerans became significant later in spring and by early July bottom organisms began to enter the diet, although cladocerans, especially *Bosmina*, remained dominant. As the young moved into deeper water, the diet began to resemble that of the adults and more aquatic insect larvae, especially chironomids, gastropods, fingernail clams (*Pisidium* spp.), amphipods (*Pontoporeia*), isopods, and ostracods were eaten; but planktonic crustaceans continued as dietary items.

The food of adult whitefish has received considerable attention, but few quantitative, in-depth studies have been made. Food varies from region to region but aquatic insect larvae, molluscs, and amphipods are primary foods. The diet of Great Lakes whitefish was composed mainly of these items according to Koelz (1929) and Hart (1931). In lakes of northern Saskatchewan, the actual foods consisted of *Pontoporeia*, fingernail clams, gastropods, chironomid larvae, mayfly nymphs, caddisfly larvae, water boatmen, leeches, water mites, mysids, and cladocerans, the items and proportions varying from lake to lake (Koshinsky 1965; Rawson 1959, 1960).

Small fishes are sometimes found in whitefish stomachs and sometimes fish eggs also. In Lake Erie, as many as five johnny darters have been found in a single whitefish stomach (Scott 1967), alewives in stomachs of

			Age (*years*)													
Population			1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+
		SL														
L. Opeongo, Ont. (Kennedy 1943)	Normal	*inches*	3.1	5.2	6.2	8.6	9.5	9.8	9.9	10.2	10.8	12.4	15.4	14.8	15.9	18.0
		mm	78	133	156	218	242	249	250	258	273	315	391	377	403	456
	Dwarf	*inches*	4.3	4.7	5.0	5.2	5.3	–	–	–	–	–	–	–	–	–
		mm	109	118	128	133	134	–	–	–	–	–	–	–	–	–
		TL														
Cliff L., NW Maine (Fenderson 1964)	Normal	*inches*	7.0	–	10.0	11.0	11.8	12.3	12.9	14.3	15.0	14.6	16.1	18.3	–	–
		mm	178	–	254	279	300	312	328	363	381	371	409	465	–	–
	Dwarf	*inches*	6.4	7.2	7.3	7.4	7.6	–	–	–	–	–	–	–	–	–
		mm	163	183	185	188	193	–	–	–	–	–	–	–	–	–

five whitefish in Lake Huron region (C. A. Lewis, personal communication), the spottail minnow was eaten in Shakespeare Island Lake (Hart 1931), *Leucichthys* sp., ninespine sticklebacks, and *Cottus* sp. in Lake Nipigon (Clemens et al. 1923), ninespine sticklebacks and the deepwater sculpin were reported from whitefish stomachs in northern Saskatchewan (Koshinsky 1965; Rawson 1959), and ninespine sticklebacks were not uncommon in stomachs examined from Beaverlodge and Red Rock lakes, N.W.T. The principal bait used when fishing for whitefish in winter at Lake Simcoe, Ont., is the emerald shiner, either salted or fresh. Feeding by whitefish on eggs of their own and other species has been observed by the following: whitefish eggs (Hart 1931), alewife eggs (Reckahn 1970), cisco eggs (Pritchard 1931; Rawson 1930b).

Small whitefish fall prey to a number of predatory fishes and, in the Great Lakes region, adult whitefish are parasitized by sea lamprey. The effect of sea lamprey predation on Lake Huron whitefish stocks was discussed by Cucin and Regier (1965), who were unable to demonstrate a significant difference in scarring rate of whitefish before and after the application of lampricide in 1961 for lamprey control. The rate of scarring fluctuated around 3% from 1959 to 1964.

The major predators of whitefish are lake trout, northern pike, burbot, yellow walleye, and even whitefish themselves at times when they consume their own eggs. Perch and ciscoes were reported to feed upon larval whitefish in Lake Ontario (Hart 1930), and burbot have been reported to eat whitefish eggs in Manitoba.

The lake whitefish, in addition to having a wide distribution, is also host to many parasite species and consequently there is abundant literature.

Hart (1930) reported the only parasite he found in Bay of Quinte whitefish fry was a glochidium on the pectoral fin of one specimen. Hart (1931) examined 113 adult whitefish from Lake Ontario and found 108 parasitized by tapeworms and hornyhead worms (acanthocephalans), 47 harboured nematodes, and 6 carried crustacean parasites. One whitefish bore a lamprey mark.

The first reported occurrence of *Cystidicola stigmatura* in western Canada was published by Smedley (1933) who found this nematode in the swim bladders of whitefish from many Canadian lakes.

Bangham and Hunter (1939) examined 24 specimens of *C. clupeaformis* from Lake Erie and found 21 infected. Parasites identified were three species of cestodes *Abothrium crassum*, *Schistocephalus* sp., *Proteocephalus exiguus*, the nematode *C. stigmatura*, and acanthocephalans *Echinorhynchus coregoni* and *Echinorhynchus* sp., and one unidentified trematode. All 15 lake whitefish taken from the west end of the lake contained parasites. Six young fish, also taken from the west end of the lake, were infected with the cestode *P. exiguus*; one specimen contained eight larval and one adult form of this cestode.

In Algonquin Park lakes 16 of the 17 whitefish examined by Bangham and Venard (1946) were infected. All contained the cestode *Proteocephalus laruei*. Other parasites were identified as cestodes *Eubothrium salvelini* and *Bothriocephalus* sp.; nematodes *Spinitectus gracilis* and *Rhabdochona* sp.; trematodes *Crepidostomum cooperi* and *C.*

farionis; acanthocephalan *Leptorhynchoides thecatus*; and the copepod, *Ergasilus caeruleus*.

All 99 whitefish which Bangham (1955) examined from Lake Huron carried parasites as follows: cestodes *Proteocephalus exiguus*, *P. laruei*, *Diphyllobothrium* sp., *Cyathocephalus americanus*, and *Triaenophorus crassus*; nematodes *Cystidicola stigmatura*, *S. gracilis*, and *Philometra* sp.; trematodes *Diplostomulum* sp. (highest incidence); acanthocephalan *Echinorhynchus salmonis*; protozoan *Lymphocystis* sp.; and copepod *Achtheres corpulentus*. Details of incidence and localities are provided in Bangham's paper.

A new species of gorgoderid trematode, *Phyllodistomum coregoni*, was described by Dechtiar (1966a) from the ureters and urinary bladder of lake whitefish caught in Lake of the Woods, Ont.

Sandeman and Pippy (1967) and Threlfall and Hanek (1970) reported infection of whitefish by acanthocephalans *Echinorhynchus lateralis* and *Acanthocephalus lateralis* in specimens taken from Mitchell's Pond, Hogan's Pond, and Hugh's Pond in Newfoundland.

The cestode parasite *Triaenophorus crassus* is of particular interest because of the marketing problem caused by the presence of its repulsive cysts in whitefish flesh. Although the cysts are unsightly, they are not harmful to man. The following outline of the life history of *T. crassus* was prepared for us by Dr G. H. Lawler of the Freshwater Institute, Fisheries Research Board of Canada, Winnipeg, where much of the work on *Triaenophorus* has been done.

T. crassus Forel is a pseudophyllidean cestode found typically in the circumpolar subregion of the Holarctic. The northern pike, *Esox lucius*, is the definitive or final host. The parasite attains sexual maturity in the gut of the pike, produces eggs at the time the pike spawns, and then dies. The embryo parasite develops in the egg, becomes a coracidium, and leaves the egg shell. This free-swimming form must be eaten by the first intermediate host, a copepod, for further development. In North America, *Cyclops bicuspidatus* is the most important copepod. In this host the parasite is transformed into a procercoid larva and the duration of this stage may last approximately one month. When an infected copepod is eaten by whitefish, ciscoes, or other members of the family Salmonidae, the procercoid burrows through the gut wall and becomes transformed into a plerocercoid larva which usually encysts in the musculature. This plerocercoid stage may remain viable for 4–5 years and if the infected fish is eaten by a pike during this period the life cycle begins again. It has been found that the degree of infection can be significantly lowered by fishing pike intensively.

Parasitized whitefish are prevented from entering the market by means of restricted fishing in highly infected lakes, rigid inspection of fish, and candling of fillets. For information on candling and associated problems, *see* Budde (1965) and Freese (1970).

Relation to man The lake whitefish is still the most valuable commercial freshwater fish in Canada, although yields have been considerably reduced in recent years because of environmental deterioration and depletion of stocks. Great Lakes landings have been reduced from a high of approximately 17.5 million pounds to a mere 3.5 million pounds in 1969.

The lowered Great Lakes production has encouraged increased yields from northern inland lakes. Even so, the latest yield of 18.3 million pounds for all Canada was the lowest in 20 years and we can expect still lower yields as inland stocks also become depleted.

The total Canadian yield and landed value of lake whitefish for the 5 years, 1964–1968, are presented in the table, p. 276, quantity shown in thousands of pounds and landed value in thousands of dollars. Notice that Manitoba is the heaviest producer, Saskatchewan second, and the Northwest Territories third. As recently as 1948, the Great Lakes alone produced 17.5 million pounds, almost equal the total Canadian production in 1968.

Whitefish are caught commercially in gillnets or trapnets (and, rarely, by hook). In the western provinces, extensive winter fisheries are conducted using gillnets set beneath the ice with the aid of a piece of apparatus called a "jigger" (McKenzie 1947). In days of great abundance in the Great Lakes, they were often seined. In Lake Ontario, Wellington County, in the 1850's, up to 40,000 whitefish could be caught in a single night in the fall using a seine 10 feet deep and 300 feet long.

For decades, Great Lakes whitefish were propagated in the hatcheries and the eyed eggs and larvae released into the lakes in the spring. Investigations into the practice failed to demonstrate its effectiveness and most of the hatcheries have been closed. For a review of this problem, *see* Miller (1946a), Lapworth (1956), Dymond (1957), Christie (1963), and Cucin and Regier (1965).

The lake whitefish is the object of active sport fisheries in many parts of its range, but particularly in inland lakes within the Great Lakes drainage system. Although they can be angled in summer, they are most readily caught in fall and winter and even in spring in some regions. Lake Simcoe has the most productive and best known sport fishery, attracting anglers every season of the year, including summer. Whitefish are caught on a small hook, usually baited with a salted or fresh emerald shiner. Prebaiting (scattering salted minnows or boiled grain on the fishing ground) is common during the winter fishery, which is the most popular. Daily catches of 50–150 whitefish by resident anglers are not uncommon according to MacCrimmon and Skobe (1970) who noted that such anglers may catch a ton or more during the season, which they sell commercially. Catches by tourist or recreational anglers are usually of the order of 1 or 2 fish per hour.

Commercially caught whitefish are sold in the round, headed and dressed, or as fresh and frozen fillets; the commercial categories are "large" (3–4 pounds), and "jumbo" (4 pounds and over), but the most common category is that called "medium" (1.5–3.0 pounds). Canned whitefish, prepared in a small cannery on northwestern Hudson Bay, is a delicious product prepared for the gourmet trade in North American cities.

The exceptionally fine flavour of whitefish has been known and appreciated for centuries. No better attestation can be given than to repeat the quotation of Richardson (1836). "Although we cannot verify that one can eat it for months without tiring, we can say from personal experience that a diet of whitefish

		Year				
		1964	1965	1966	1967	1968
N.B.	*lb*	–	–	2	1	1
	$	–	–	0+	0+	0+
Que.	*lb*	107	101	90	87	39
	$	17	19	18	12	7
Ont.	*lb*	3230	3235	2813	2797	2906
	$	728	784	706	743	917
Man.	*lb*	7283	7454	6035	5642	5289
	$	1090	1159	1002	992	1076
Sask.	*lb*	6121	7607	6498	5388	4750
	$	730	851	827	534	675
Alta.	*lb*	1536	1676	2087	2074	2018
	$	244	315	397	401	445
B.C.	*lb*	–	–	–	–	–
	$	–	–	–	–	–
N.W.T.	*lb*	4467	4011	2807	2435	3208
	$	645	765	552	535	634
Yukon	*lb*	210	152	178	105	89
	$	5	3	5	3	3
Can.	*lb*	22,954	24,236	20,510	18,529	18,300
Total	$	3459	3896	3507	3220	3757

alone, with no other food, can be eaten for days, without losing its appeal." The liver, when cooked, is also of fine flavour and texture and can be made into an excellent paté. Whitefish eggs, when properly prepared, are sometimes marketed as caviar.

Nomenclature

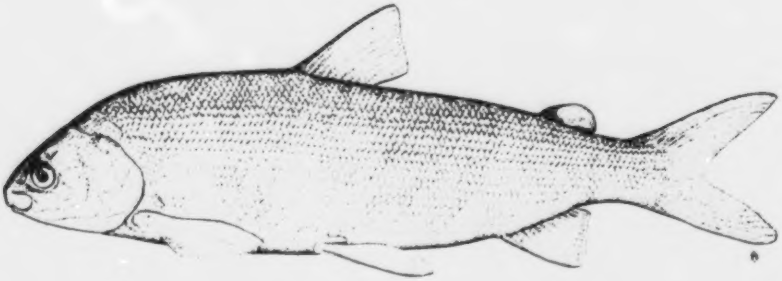
Salmo clupeaformis	— Mitchill 1818a: 321 (type locality Falls of St. Mary, northern extremity of Lake Huron)
Coregonus albus	— LeSueur 1818a: 232
	— Perley 1852: 204
Salmo (Coregonus) Labradoricus (Richardson)	— Richardson 1836: 206
Coregonus clupeiformis DeKay	— Agassiz 1850: 339
Coregonus sapidissimus Agass.	— Agassiz 1850: 344
Coregonus latior Agass.	— Agassiz 1850: 348
Coregonus clupeiformis (Mitchill)	— Evermann and Smith 1896: 297
Coregonus labradoricus Richardson	— Evermann and Smith 1896: 302
	— Cox 1896b: 67
Coregonus clupeaformis Mitchill	— Jordan and Evermann 1911: 35
Coregonus odonoghuei	— Dymond 1943: 228
Coregonus atikameg	— Dymond 1943: 228
Coregonus nelsonii Bean	— Dymond 1943: 228
Coregonus kennicotti Bean	— Dymond 1943: 228

Etymology *Coregonus* — angle-eye, coined by Artedi from the Greek words meaning pupil (of the eye), and angle; *clupeaformis* — herring-shaped.

Common names Lake whitefish, common whitefish, Sault whitefish, whitefish, eastern whitefish, Great Lakes whitefish, humpback whitefish, inland whitefish, gizzard fish. French common name: *grand corégone*.

BROAD WHITEFISH

Coregonus nasus (Pallas)



Description Body elongate, thick and heavy set, less streamlined or tapered than *C. clupeaformis*, average total length about 18 inches (457 mm), compressed laterally, greatest body depth in front of dorsal fin. Head deep, wide and short, its length 18–23% of total length; eye small; mouth inferior, distinctly overhung by snout, maxillary extending posteriorly scarcely to below anterior margin of eye, but sometimes beyond margin, maxilla length 19–23% of head length; weak teeth on lingual plate. Gill rakers total range 18–25, length of longest gill raker 13–19% of interorbital width. Branchiostegal rays 8 or 9. Fins: dorsal adipose present, sometimes large and conspicuous; dorsal 1, rays 10–13; caudal distinctly forked; anal rays 11–14; pelvic rays 11 or 12, pelvic axillary process present; pectoral rays 16 or 17. Scales cycloid, large, 84–102 in lateral line. Pyloric caeca about 148. Vertebrae 60(3), 62(5), 63(1).

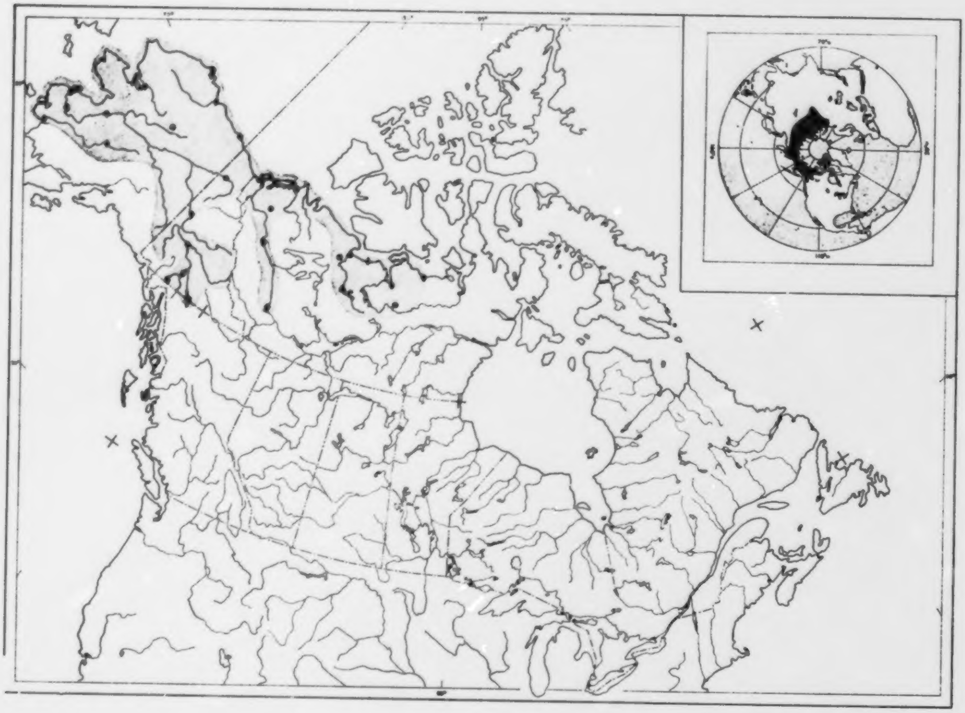
Nuptial tubercles or pearl organs developed on scales on flanks of breeding males, smaller and fewer on females.

See also Lindsey (1962) and McPhail and Lindsey (1970), the latter the source for some data given above.

Colour Overall colouration silvery with a greyish cast, sometimes with light brown tinge enhanced by darkened scale margins; back olive-brown to black, silvery on sides and silvery white below, sometimes yellowish. Cheeks and opercles often with brown, freckle-like spots. Fins of adults smoky or pearl grey, sometimes darker and more or less opaque, pelvics usually lighter; pectoral, and sometimes anal, with bluish or purplish iridescence; fins light on young or immature specimens.

Systematic notes The broad whitefish was described by Pallas (1776) based on specimens from the Bay of Ob, USSR. The first description of the North American form under the name *Coregonus kennicotti*, is credited to Milner, in Jordan and Gilbert (1883). Since 1871 (Dall) the nomenclature for the species has been most confused. Dymond (1943) erroneously synonymized *C. kennicotti* and *C. clupeaformis*; and in 1957, Svärdson expressed the view that the North American *C. clupeaformis* was a synonym of the Eurasian *C. nasus*, a view expressed previously by Dymond (1943).

Fortunately, the numerous collections made in the Northwest Territories by the Fisheries Research Board of Canada in 1959 were available to Lindsey (1962) who presented a thorough systematic review of the broad whitefish in North America. He demonstrated the distinctness of *C. nasus* from *C. clupeaformis* by using such characters as gill raker length plotted against interorbital width, dorsal profile of head, and other characters. Gill raker counts alone are not diagnostic. Few biologists who have had the



opportunity of working with both species in the field would be likely to confuse them. For a thorough discussion of the systematics and relationships of this species, *see* Lindsey (1962).

Distribution The broad whitefish is distributed in the fresh and brackish waters of the arctic drainages of northwestern North America and northern Eurasia, south to about the 60th parallel. The western limit of range is the Pechora River, USSR, just west of the Ural Mountains, from which it occurs east, to the Bering Sea. In North America, it occurs from the Perry River, N.W.T., west in numerous river systems of arctic Canada (such as the Coppermine, Mackenzie, and the headwaters of the Yukon River, including Teslin Lake, B.C.), and offshore only to Herschel Island in Beaufort Sea, to the Kuskokwim River, Bering Sea drainage, Alaska. As has been amply demonstrated by Lindsey (1962), it is *not* found in Great Bear Lake.

Biology The biology of the broad whitefish is not well known, partly because of confused taxonomy but, also, because of its northern distribution. Much of the following information was taken from Wynne-Edwards (1952), whose observations on northern fishes have been exceptionally valuable. He noted that it spawned in rivers in July and August, somewhat earlier than the humpback whitefish (*C. clupeaformis*). McPhail and Lindsey (1970) noted, however, that a specimen taken in the Yukon River, near Dawson City, on October 4, had tubercles and well-developed eggs. In the Mackenzie, at Arctic Red River, females outnumbered males by 12–15 to 1. The eggs are large and are pale yellow in contrast to the orange-yellow eggs of the humpback. The downstream migration of spawners may occur in midwinter Wynne-Edwards noted, "since there was formerly an important winter fishery for broad whitefish about Minto and Pelly Crossing in the Yukon Territory."

No growth studies of Canadian populations are available, but in the Yenisei River, Siberia, the broad whitefish matures at about age 7 and lives to 15 years and older (Nikol'skii 1954). It is believed to grow larger than the humpback whitefish (*C. clupeaformis*) at least in the lower Mackenzie, where the broad whitefish is said to attain weights of over 4 pounds (2 kg) (Wynne-Edwards 1952). It is said to attain weight of 30.6 pounds (16 kg) in the Kolyma River, Siberia.

It is found more frequently in rivers than lakes and is occasionally taken in brackish waters. In Siberia, Nikol'skii noted that it overwintered in river channels and large lakes.

Its food is said to consist of bottom organisms, such as aquatic insect larvae, small molluscs, and crustaceans.

No list of parasites of broad whitefish in Canadian waters has been published. A summary of parasites occurring in USSR specimens was compiled by Bykovskaya-Pavlovskaya et al. (1962) and included by Lawler (1970).

Relation to man In the northwest, the broad whitefish is taken by gillnet for local consumption only, for use as both human and dog food. It is an esteemed food fish and the white flesh is delicately flavoured. It is eaten fresh but is also preserved by splitting and air-drying or smoking.

For further information *see also* Wynne-Edwards (1947, 1952) and McPhail and Lindsey (1970).

Nomenclature

Salmo (Coregonus) nasus	— Pallas 1776: 705 (type locality Bay of Ob, USSR)
Coregonus nasus	— Günther 1866: 177
	— Dymond 1943: 192
Coregonus kennicotti	— Milner *in* Jordan and Gilbert 1883a: 298
Coregonus nasus kennicotti	— Wynne-Edwards 1952: 13
Coregonus nasus kennicotti Milner	— Cohen 1954: 169
Coregonus nasus (Pallas)	— Walters 1955: 281

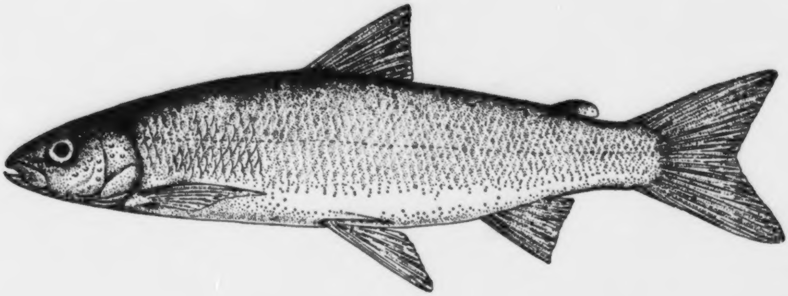
(*See* also Lindsey (1962) for a detailed discussion of the nomenclature.)

Etymology *Coregonus* — angle-eye, coined by Artedi from Greek words meaning pupil (of the eye), and angle; *nasus* — referring to shape of nose.

Common names Broad whitefish, round-nosed whitefish, sheep-nosed whitefish, khlugu-zhey, tezareh, tezra. French common name: *corégone tschir*.

ATLANTIC WHITEFISH

Coregonus canadensis Scott



Description Body elongate and terete, average length to about 15 inches (381 mm), compressed laterally but less so than lake whitefish, greatest body depth at front of dorsal fin 18–22% of total length. Head relatively short, about 20% of total length, never observed to have nuchal hump; eye small, its diameter 17–24% of head length, adipose eyelid distinct; snout length 25–28% of head length, always greater than eye diameter; mouth usually terminal and upper and lower jaws equal on small or medium-sized fish when mouth closed, upper jaw or snout projecting slightly on large males, maxillary extending to below anterior part of eye, seldom to below pupil, maxilla length 25–30% of head length; small but well-developed teeth present on premaxillaries, vomer, palatines, dentary, and tongue at all ages. Gill rakers, extreme range 23–27, usually 25 or 26, length of longest gill raker 23–50% of interorbital width. Branchiostegal rays 6–9. Fins: dorsal adipose present; dorsal 1, rays 10–12; caudal distinctly forked; anal rays 9–12; pelvic rays 11 or 12, pelvic axillary process long, exceeding maxillary length at all ages; pectoral rays 15 or 16. Scales cycloid, moderately large, 91–100 in lateral line. Vertebrae 63 or 64.

Nuptial tubercles or pearl organs developed on males at least, on scales on flanks and also on top (few) and sides of head.

Colour Overall colouration silvery; dark blue to dark green on the back, becoming silvery on the sides and silvery white below. Dorsal and caudal fins dusky, lower fins light.

Distribution Restricted to Nova Scotia, where it is known to occur in Millipsigate Lake, (and possibly other nearby lakes) and also in the Tusket River system. In the latter, there was a regular downstream and upstream movement, and some whitefish at least moved out of the estuary into fully salt water. Some specimens were caught in Yarmouth Harbour.

Biology We know little about the biology of this whitefish. It is fairly certain that the Tusket River population was anadromous for there was said to be a definite and regular upstream migration, (a spawning run?) in October. The species grows to a length of at least 20 inches (508 mm).

Stomach contents of specimens taken in Yarmouth Harbour yielded amphipods, small periwinkles (*Littorina littorea*), and marine worms. It is assumed that Millipsigate Lake specimens ate aquatic insect larvae and other invertebrates.

Relation to man Interviews with local residents indicate that prior to 1965, the

Tusket River population was ruthlessly exploited during the upstream movement in October. The building of a hydro-electric dam and the installation of a fish ladder, which was not supervised, exposed the migrating fish to easy capture by poachers with dipnets. The Tusket River population appears to be seriously depleted.

Nomenclature

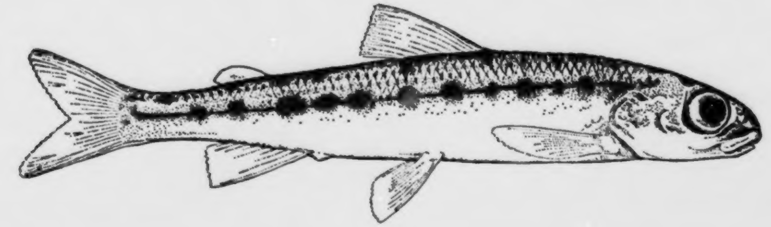
Coregonus labradoricus Richardson	— Piers 1927: 92
Coregonus clupeaformis (Mitchill)	— Dymond 1947: 8
Coregonus sp.	— Leim and Scott 1966: 104
Coregonus canadensis	— Scott 1967: 26

Etymology *Coregonus* — angle-eye, coined by Artedi from the Greek words meaning pupil (of the eye) and angle; *canadensis* — in reference to Canada, the only place it occurs.

Common names Atlantic whitefish, whitefish, Sault whitefish. French common name: *corégone atlantique*.

PYGMY WHITEFISH

Prosopium coulteri (Eigenmann and Eigenmann)



Description Body elongate, about 4–5 inches (102–127 mm) total length, almost cylindrical, body depth less than twice body width, and, hence, body only slightly compressed laterally except in region of caudal peduncle, females deeper bodied than males. Head elongate, its length slightly greater than body depth; eye relatively large, its diameter greater than snout length; snout bluntly rounded, overhanging mouth, not as obviously pointed as in *P. cylindraceum*, a single flap of skin between nostrils; mouth small, ventral in position, overhung by snout; maxillaries extending posteriorly from anterior edge of orbit to centre of eye; teeth small, restricted to tongue, absent from jaws, vomer, and palatines. Gill rakers short, 6.5–8.8% of head length, total count, 11–21, upper limb of gill arch 3–7, lower limb 8–13, but McCart (1970) studied many samples and recorded a range of 12–21. Branchiostegal rays 6–9 + 6–9 (McPhail and Lindsey 1970), but 7+7(3), 8+7(1), 8+8(6), in Lake Superior. Fins: Eschmeyer and Bailey

(1955) noted that on mature fish rayed fins always larger on males than females; small adipose dorsal present; dorsal 1, 10–12 rays; caudal distinctly forked; anal rays 10–14; pelvic rays 9–11, axillary process present; pectoral rays 13–18, axillary process absent. Scales cycloid, large; lateral line complete, 50–70 pored scales. Pyloric caecae simple, low in number, 13–33. Vertebrae 50–55 (McPhail and Lindsey 1970) but in Lake Superior 52(2), 53(7), 54(1) (Eschmeyer and Bailey 1955).

Nuptial tubercles developed on both males and females, more conspicuous on males, and occur on top of head, on scales on back and sides, and on paired fins.

For additional morphometric and meristic data *see* section on *Systematic notes* and *also* Eschmeyer and Bailey (1955) and McCart (1970).

Colour Brownish above, silvery on the sides and white below. Dorsal, caudal, and pectoral fins usually clear, anal and pelvic whitish and immaculate, a faint dark spot sometimes present on base of caudal fin. A series of 12–14 similar spots along midline of back, and 7–14 dark, round or oval parr marks with diffuse borders along lateral line of young and subadults, usually vague or absent on adults, although some Alaskan forms retain parr marks even on largest fish (McCart 1970). The use of the term "parr marks" may be misleading but *see* comments on colour of *Prosopium cylindraceum*.

Systematic notes This rather well-defined species was poorly known until quite recently. Although once thought to be rare, it is now known to be more common than formerly supposed (McCart 1965). Still puzzling, however, are the peculiarly isolated Lake Superior populations. It might be, as suggested by McPhail and Lindsey (1970), that this small species is present in intervening lakes but has not been collected. The Lake Superior populations were not detected until 1952 when a bottom trawl was fished at depths over 60 feet (18.3 m).

The existence of sibling species of pygmy whitefish was discussed by McCart (1970), who presented evidence of sympatric populations of low gill raker forms and high gill raker forms in Alaskan lakes. Such evidence was not available to Eschmeyer and Bailey (1955), who concluded that the differences between widely separated populations was slight. Evidence available to date, especially that presented by McCart (1970), suggests that the Lake Superior population is sufficiently divergent from western populations to have had a Mississippian glacial refugium, while western populations may have redispersed from a Yukon–Bering Sea refugium (high gill raker form), or a western refugium south of the ice sheet (low gill raker form).

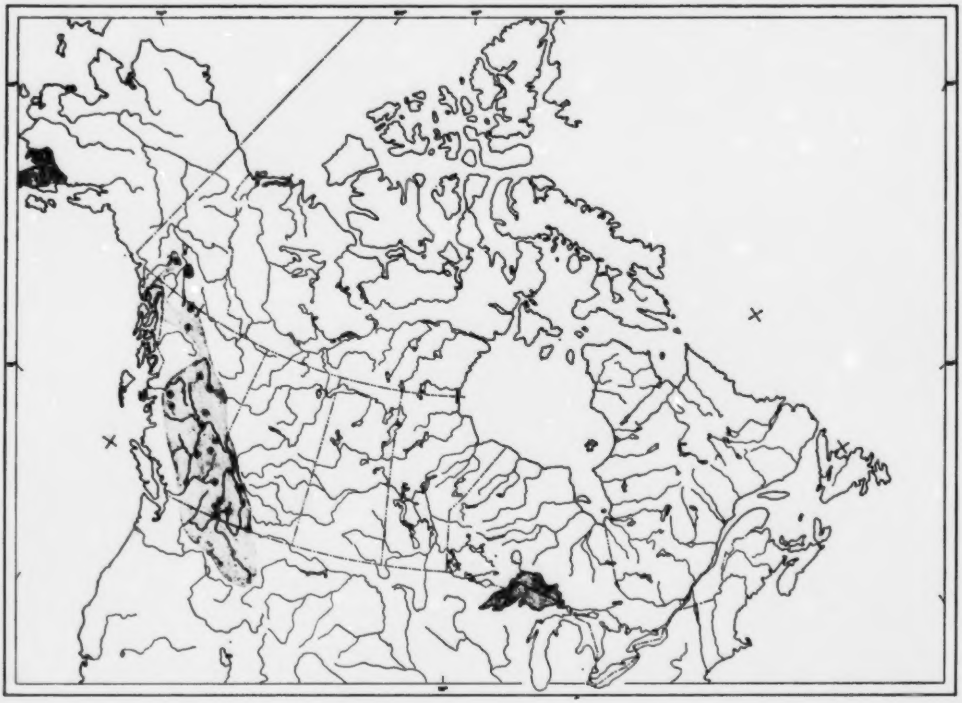
For additional information, *see* Eschmeyer and Bailey (1955), McCart (1965, 1970), Heard and Hartman (1966), and McPhail and Lindsey (1970).

Distribution The pygmy whitefish has a disjunct or discontinuous distribution in North America. It occurs in the Columbia River system in western Montana and Washington, in British Columbia, Yukon Territory, and in the Bristol Bay and Alaska Peninsula region of southwestern Alaska.

In Canada, it occurs in the Columbia, Fraser, Skeena, Peace, and Liard River systems in British Columbia, and in the upper Yukon River system (Teslin River) and Alsek River system in British Columbia and Yukon Territories. In the east, it occurs in Lake Superior where its presence went undetected until 1952.

Biology Information on spawning is meagre but available evidence suggests that it usually takes place in October, November, or December, depending on the region. Indirect evidence gathered by McCart (1965) in British Columbia lakes suggested spawning occurred in October or November. In Bull Lake, Mont., spawning occurred in December and January in 1952–1953, and in Lake Superior, the capture of unripe fish in October and spent fish in January, indicated November–December spawning.

Spawning is assumed to take place in shallow water, in streams or lakes. The eggs are



probably scattered over coarse gravel and develop over winter emerging from gravel in early spring. The eggs, large when ripe, measured 2.0 mm in diameter in specimens from Lake Superior and 2.4 mm in specimens from the Naknek River system in Alaska. A female of 5.1 inches (130 mm) total length from Lake Superior averaged about 440 eggs while a female of the same length from Naknek River system averaged 580 eggs (Heard and Hartman 1966).

Growth is slow and the maximum size attained is small. Females grow faster and live longer than males. In Maclure Lake, B.C., females live longer than elsewhere, attain an age of 9 years, and a fork length of 10.7 inches (271 mm), whereas males reach 6 years of age and a fork length of 8.9 inches

			Age (*years*)								
			1+	2+	3+	4+	5+	6+	7+	8+	9+
Keweenaw Bay, L. Superior (Eschmeyer and Bailey 1955)	TL *inches*	M	3.0	3.7	4.0	4.2	4.3	–	–	–	–
		F	3.0	4.0	4.2	4.7	5.0	5.0	5.0	–	–
	mm	M	76	94	102	107	109	–	–	–	–
		F	76	102	107	119	127	127	137	–	–
Cluculz L., B.C. (McCart 1965)	FL *inches*	M	–	3.6	4.5	4.6	4.6	4.8	–	–	–
		F	–	3.2	4.3	4.8	5.0	5.6	6.2	–	–
	mm	M	–	92	113	116	116	122	–	–	–
		F	–	81	110	121	127	142	156	–	–
Maclure L., B.C. (McCart 1965)	FL *inches*	M	–	4.8	7.6	8.3	7.3	8.9	–	–	–
		F	–	4.6	7.5	8.6	9.6	9.8	10.1	–	10.7
	mm	M	–	121	192	210	185	225	–	–	–
		F	–	117	190	219	245	248	257	–	271

(225 mm). A table of comparative lengths at various ages appears on p. 284.

In Lake Superior the pygmy whitefish is a deepwater species, with a depth range of from 60–294 feet (18.3–88.6 m), but the largest catches are made at 180–234 feet (54.9–70.3 m). There is no change in depth distribution with season. In the Pacific drainage, this whitefish thrives in lakes and the flowing waters of clear or silted rivers of mountainous country. In western lakes, it lives in shallower water than in Lake Superior, but usually deeper than 20 feet, although it may also occur in shallows.

The pygmy whitefish is apparently quite adaptable in feeding habits. Crustaceans and aquatic insect larvae, especially chironomids, are the primary foods. In Lake Superior, ostracods and *Pontoporeia*, are principal crustaceans eaten but copepods are important in diet of young fish. In Alaskan lakes, chironomids were also important but, in addition, plecopteran larvae were consumed and planktonic crustaceans were also significant in the diet. In both Lake Superior and Alaskan lakes, fish eggs were eaten, and it is probable they are important in the diet. In Alaska the eggs appeared to be salmon eggs, in Lake Superior, coregonine eggs. *See* Eschmeyer and Bailey (1955) and Heard and Hartman (1966) for further information.

Predation on pygmy whitefish is poorly documented. They were reported to be caught by kingfishers at the surface of a lake in Washington (Snyder 1917) and terns (*Sterna paradisaea*) were observed to be catching presumed pygmy whitefish at the surface of a lake in the Naknek River system in Alaska (Heard and Hartman 1966).

Apparently the parasites associated with the pygmy whitefish have not yet been reported.

Relation to man It is of no known direct economic importance, and its indirect importance as a forage species, for example, in Lake Superior, is unknown, but it is eaten by arctic char and Dolly Varden in the northwest.

Elsewhere, when abundant, as in some Alaskan lakes, it may compete for food with young sockeye salmon, or may act as a buffer between salmon predators and young salmon (Heard and Hartman 1966).

The remarkably discontinuous distribution pattern and systematic variation provide data of especial interest to students of North American zoogeography and postglacial dispersion.

Nomenclature

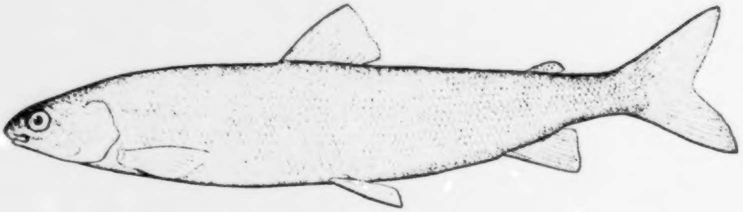
Coregonus coulterii E. and E. — Eigenmann and Eigenmann 1892: 961 (type locality Kicking Horse River at Field, B.C.)
Coregonus coulteri Eigenmann and Eigenmann — Eigenmann 1895: 115
Prosopium Milner — Hubbs 1926: 13
Prosopium coulteri (Eigenmann and Eigenmann) — Jordan, Evermann, and Clark 1930: 65
Prosopium snyderi — Myers 1932: 62
Prosopium coulterii (Eigenmann and Eigenmann) — Dymond 1947: 8

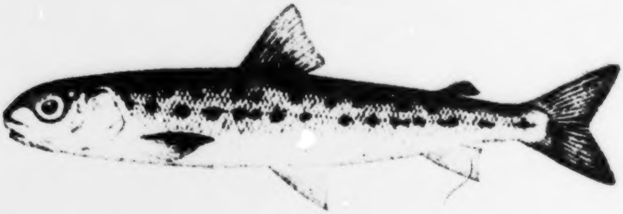
Etymology *Prosopium* — a mask, from the large bones in front of the eyes; *coulteri* — after Dr J. M. Coulter, a distinguished botanist.

Common names Pygmy whitefish, Coulter's whitefish, brownback whitefish. French common name: *ménomini pygmée*.

ROUND WHITEFISH

Prosopium cylindraceum (Pallas)

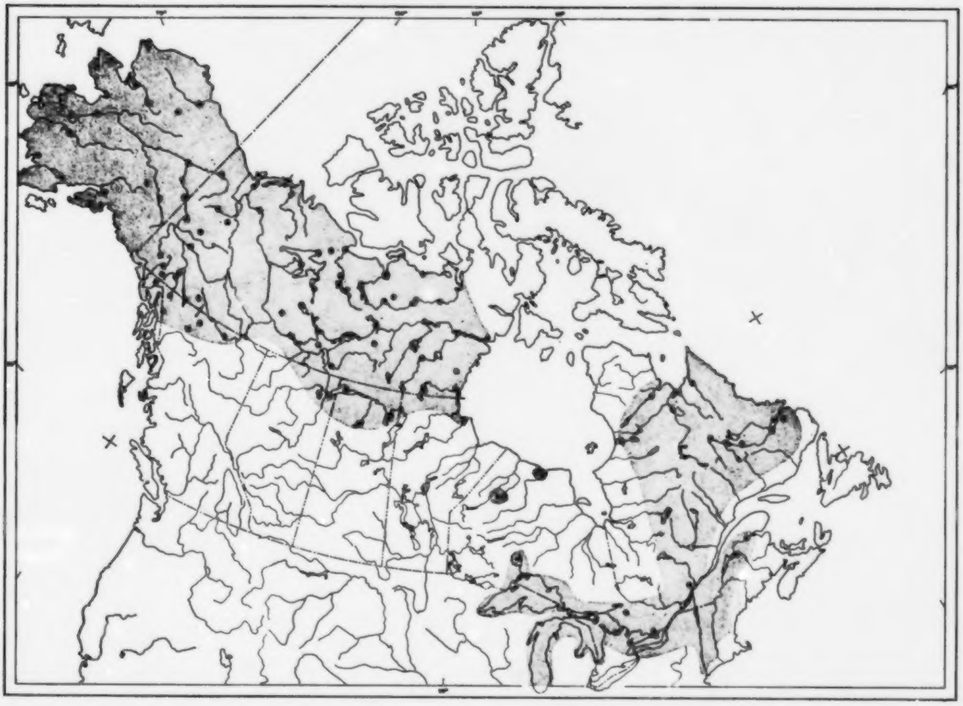




Description Body slender, elongate, average length about 8–12 inches (203–305 mm), almost cylindrical in cross section, greatest depth in front of dorsal fin, posteriorly body somewhat compressed laterally. Head relatively short, its length about 20% of total length; eye moderate, its diameter less than snout length; snout pointed, "pinched" or compressed laterally, rounded in lateral view, a single flap of skin between nostrils; mouth small, ventral in position, overhung by snout; maxillaries extending posteriorly almost to anterior margin of eye of adults; teeth small, restricted to a small central patch on tongue, and on bases of gill rakers, but absent from jaws, vomer, and palatines. Gill rakers short, total range 14–21, upper limb of gill arch 5–8, lower limb 9–13, usually 15–17 in Great Lakes region, 17–21 in Northwest Territories, gill rakers with teeth at bases (Norden 1970). Branchiostegal rays 6–9 + 7–9, commonly 7+7 to 8+8. Fins: small adipose dorsal present, dorsal 1, with 11–15 rays; caudal distinctly forked; anal rays 10–13; pelvic abdominal, 9–11 rays, a pelvic axillary process present; pectoral rays 14–17, no pectoral axillary process. Scales cycloid, large, those on back outlined with dark pigment; lateral line complete, scales variable, ranging from 74–108 over whole range (*see* Walters 1955, who gave table of comparative counts with total range of 74–106 scales). Pyloric caecae variable, range 50 (Lake Ontario) to 130 (Northwest Territories). Vertebrae 58–65 over whole range but in Lake Huron 62(6), or 63(3), in Northwest Territories 62(1), 63(7), 64(1).

Nuptial tubercles (based on observations on specimens caught in Owen Channel, Lake Huron, November 9–10, 1958) well developed on males, less so on females, one tubercle per scale, located on centre of exposed field of scale for first 5 rows of scales above and below lateral line; a few smaller tubercles on nape, none on head.

Colour The round whitefish has more colour than most coregonids. Overall colouration of adults almost silvery but back sepia brown or almost bronze, with green tinge, sides silvery, silvery white below. Scales, especially on back, with well-defined, dark, pigmented borders, making them conspicuous. Pectoral fins are amber in colour, slight amber tint also to pelvic and anal fins. Pectorals take on an orange tint during spawning, pelvic and anal fins also, to a lesser extent. A light dusting of black pigment may occur on



dorsal and caudal, very lightly on margin of anal, and on dorsal surface of pelvic and pectoral fins. The adipose is usually brown spotted, particularly on specimens in central and eastern Canada.

Young are silvery with two or more longitudinal rows of black spots on sides. Compare illustrations of adult (*above*) and young (*below*) on p. 286. The conspicuous lower row of 10 or more spots occurs along the lateral line; just below the midline of the back is a series of 10 or more spots that may coalesce with spots across the back. Between these two rows is a series of marks or pigmentation concentrations of variable sizes, not always recognizable as spots.

Black spots on midline of sides are most intense at lengths of 2–3 inches (51–76 mm), but may be visible on dead specimens up to 10.5 inches (267 mm) long. They are sometimes called parr marks but this word is perhaps somewhat misleading when applied to *P. cylindraceum*, for the marks are round, or, at most, longitudinally ovoid, and much less ventrally ovoid than in chars, *Salvelinus* spp., or related species.

Systematic notes McPhail and Lindsey (1970) remarked upon the apparent discontinuity of the Canadian distribution in the vicinity of the Manitoba–Ontario border, and the possible existence of two morphological types. The northwestern populations were said to have high mean gill raker counts (17.8–19.2) and high pyloric caeca counts (94.1–106.2) while eastern populations have low gill raker counts (16 or 17) and pyloric caeca (67.6–82.8). These authors theorize that the differences have resulted from postglacial dispersion from two refugia rather than from environmental differences, since clinal variation cannot be demonstrated. Available evidence suggests that vertebrae numbers exhibit the same trend as gill rakers and pyloric caecae.

Distribution The round whitefish ranges widely through northern North

America and into northeastern Asia, where it is found from the Yenisei River to Bering Strait and Kamchatka Peninsula. In North America, it is found in a single lake in Connecticut, (East Twin Lake), from the New England states and from Labrador on the east, to Alaska in the northwest.

In Canada it ranges from northern New Brunswick, Labrador, and Ungava west through parts of Quebec, Ontario, and the Great Lakes, including Lake Nipigon but excluding Lake Erie. Farther north in Ontario it has been reported from the mouth of the Winisk River and Big Trout Lake.

The distribution is discontinuous in the general region of the Ontario–Manitoba border. Thence, from northern Manitoba the species is distributed northwestward through the Territories and northern British Columbia to Alaska.

Biology Spawning takes place in the fall of the year in the gravelly shallows of lakes, at river mouths or, on occasion, in rivers. It usually occurs in November in the Great Lakes region and earlier northward. In lakes Michigan and Huron, Koelz (1929) established that round whitefish spawned in November, over gravel, at depths of 12–48 feet. In Lake Superior, experimental fishing in 1960 indicated spawning took place in late November and early December over a gravel and rock bottom at a depth of 21 feet and a temperature of 40° F (4.5° C). Near Nueltin Lake, on the border of Manitoba and the Northwest Territories, an upstream spawning migration was noted in late October (Harper 1948). In New Hampshire, fish began arriving on the spawning grounds during the last two weeks of November (Normandeau 1969) and the peak of spawning activity occurred about the second week of December. Males usually arrive on spawning grounds before females, but neither males nor females eat during prespawning or spawning activities. Normandeau noted that the fish swam in pairs during spawning and did not form large spawning schools. In common with other whitefish, no parental care is given eggs or young.

The eggs are orange in colour and are large for a coregonid. In New Hampshire, unfertilized ova ranged in diameter from 2.4–2.9 mm and, after a few hours in water, attained maximum diameters, ranging from 3.3–4.6 mm. The number of eggs deposited by spawning females is not known but fecundity for Lake Superior fish was estimated by Bailey (1963). The number of eggs in ovaries of females ranging in total length from 12–17 inches (305–432 mm) increased from an average of 2461 for the smaller size to 10,459 for the larger. The largest number of eggs for a single female was 11,888. Using data from 37 females, Bailey calculated an average production of 341 eggs per ounce of fish. Normandeau observed and collected newly hatched fry on March 31, 1962, but considered that the peak of hatching occurred during the last week of April, and that all were hatched by May 11. He calculated that 140 days at 36° F (2.2° C) was, therefore, required for development, considering that the peak of spawning occurred about the end of the first week of December. This figure of 140 days to hatching is similar to the time to hatching required by lake whitefish as described by Hart (1930).

In common with other coregonine fishes, the age of individuals can be determined by examining the scales. The lengths at various ages for a number of populations are shown in the accompanying table. Note that length is sometimes given as fork length, at other times as total length. The growth rate in Lake Michigan is obviously much higher than in Canadian lakes, particularly in the Ungava region. Great Slave Lake growth rates, however, are remarkably good and are higher than those for Lake Superior. The maximum size is probably 22.1 inches (561 mm) total length, a 13-year-old fish from Great Slave Lake. Keleher (1961) listed a 4.5-pound specimen, 508 mm fork length. Koelz (1929) gave a maximum size for Lake Superior of "about 5 pounds" but provided no further details.

In the more southerly parts of its range, the round whitefish is usually found in deep lakes, although it is not known to inhabit the deeper waters regularly. In the Great Lakes,

		Age (*years*)													
		1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+
	FL														
Ungava (Koksoak R.)	*inches*	–	6.0	6.9	7.9	8.7	9.5	10.5	11.6	12.0	12.6	13.9	14.6	–	–
(Mackay and Power 1968)	*mm*	–	152	175	201	221	241	266	294	305	320	352	370	–	–
	TL														
Great Slave L., N.W.T.	*inches*	3.5	7.0	11.2	10.5	13.4	14.6	15.8	17.4	18.4	20.6	–	20.1	22.1	20.2
(Rawson 1951)	*mm*	89	178	284	267	340	371	401	442	467	523	–	511	561	513
	FL														
Great Bear L., N.W.T.	*inches*	–	–	–	–	12.9	13.3	13.9	14.5	16.6	–	–	–	–	–
(Kennedy 1949b)	*mm*	–	–	–	–	328	338	353	368	421	–	–	–	–	–
	Wt (*oz*)	–	–	–	–	14	14	16	19	32	–	–	–	–	–
	TL														
L. Michigan	*inches*	–	12.2	14.2	15.5	17.4	18.3	19.6	–	–	–	–	–	–	–
(Mraz 1964b)	*mm*	–	310	361	394	442	465	498	–	–	–	–	–	–	–
	TL														
Apostle Is., L. Superior	*inches*	4.3	7.1	9.0	10.7	12.0	13.0	14.0	15.0	15.5	–	–	–	–	–
(Bailey 1963)	*mm*	109	180	229	272	305	330	356	381	394	–	–	–	–	–

Lengths calculated to exactly *n* years, rather than *n*+ years.

Koelz (1929) considered it to be a shallow-water species, inhabiting water less than 150 feet (45.7 m) deep. More recent investigations in the Great Lakes support this view and Dryer (1966) noted that in western Lake Superior it was most abundant at depths less than 120 feet (36.6 m), and that none were caught at depths greater than 236 feet (71.9 m). However, in August, 1959, the United States Fish and Wildlife vessel M/V *Cisco* caught a single round whitefish in bottom gillnets set in 600 feet (218.9 m) in eastern Lake Superior off Grand Marais, Mich., the greatest depth recorded for the species.

In the northerly parts of its range and elsewhere, such as Quebec and New Brunswick, round whitefish may be found in rivers or streams. It has been reported in brackish water on both sides of Hudson Bay (Dymond 1933; McAllister 1964b) and off the mouths of the Coppermine and Mackenzie rivers, although Backus (1957) remarked on its absence in brackish waters in Labrador.

This bottom-feeding whitefish eats a variety of benthic invertebrates, especially mayfly larvae and pupae, caddisfly and chironomid larvae, and small molluscs such as fingernail clams and snails. Such food items as these have been reported from inland lake populations across Canada but, in addition, Rawson (1959) noted crustaceans *Hyalella* and the remains of a small fish in stomachs from Saskatchewan's Cree Lake. Fish was also reported in stomachs of samples caught in July in Atlin Lake in northern British Columbia (Withler 1956).

A comprehensive study of food was carried out in Algonquin Park lakes by Sandercock (1964), who remarked on the apparent competition for food between round and lake whitefish and on the depressed growth rate of *P. cylindraceum* when *Coregonus clupeaformis* was present. The lower growth rate was attributed to the greater efficiency by *C. clupeaformis* in procuring planktonic organisms for food.

The species is also known or at least suspected to feed on the eggs of other fishes, such as lake trout (Loftus 1958). Martin (1957) expressed the view that round whitefish may have been a serious predator on lake trout eggs in Lake Opeongo, but had no direct evidence. In Lake Ontario, Hart (1930) reported finding 30 lake trout eggs in one round whitefish stomach, but no lake whitefish eggs. During exploratory fishing activities by the United States Fish and Wildlife Service in Lake Superior in November and December, 1958, a large number of round whitefish were examined for possible predation on lake whitefish eggs but only one round whitefish had eaten eggs and these were possibly round whitefish eggs. Harper (1961) reported fish, presumed to be round whitefish, present on longnose sucker spawning grounds in Labrador. Its reputation in former years for "waiting on" shad (whence the name "shad waiter") and then eating their eggs in one or two New Hampshire lakes was reviewed by Harper.

Lake trout are known to prey upon round whitefish (Dymond 1928b; Martin 1957; Harper 1961) but usually not as a major item of diet. Other than the above casual observation of trout stomachs, Normandeau (1969) who worked on Newfound Lake, N.H., provided one of the few accounts of predation on the species. Brown bullheads and burbot consumed eggs on the spawning grounds, and yellow perch and white suckers were also presumed to have fed on eggs. Yellow perch are known to be serious predators on eggs of lake whitefish and it is probable that they are also significant predators on those of round whitefish, since the two whitefishes utilize similar types of spawning grounds. In Newfound Lake, Normandeau found spent female round whitefish were also feeding on eggs. The same author noted that predation on newly hatched fry may be heavy. In May, he examined two Atlantic salmon, *Salmo salar*, that had over 200 fry in their stomachs. From the same lake, a 10-inch (254-mm) round whitefish was found in the stomach of a chain pickerel, *Esox niger*.

The round whitefish appears to support a rather large parasite fauna. All specimens examined by Bangham (1941) and Bangham and Venard (1946) from Lake Opeongo, Algonquin Park, Ont., were infected. Parasites identified were trematodes *Crepidostomum farionis* and *C. cooperi*, copepods *Ergasilus caeruleus* and *E.* sp., nematode *Spinitectus gracilis*, and the acanthocephalan *Leptorhynchoides thecatus*. Bangham (1955) examined 22 specimens from Lake Huron and Manitoulin Island and found all infected. A total of 10 parasite species were recorded, and two of the whitefish represented a new host for the acanthocephalan *Neoechinorhynchus tumidus*.

An important parasite of most coregonine fishes, including this species, is the cestode, *Triaenophorus crassus*, which infects members of northwestern populations (Lawler and Scott 1954). For additional information on *Triaenophorus see* account in *Coregonus clupeaformis*.

See also Bangham and Adams (1954) for a list of parasites attacking the species in British Columbia waters, and Hoffman's (1967) checklist of parasites of this whitefish in North American fresh waters.

Relation to man The flesh is of fine quality and it is usually highly regarded as a food fish by the relatively few who have eaten it. It is sought by anglers to a limited extent in the rivers and streams of northwestern New Brunswick.

It is of minor commercial importance in Canada largely because of small average size and fluctuating supply. Commercial landings between 1960 and 1968 from Ontario waters, principally Lake Huron and Lake Superior, under the name "menominee," fluctuated from 20,000 to 70,000 pounds and were valued at $1500 to $10,000. It supported a larger fishery in United States Great Lakes waters in past years. Bailey (1963) reported annual yields of upwards of 250,000 pounds in Lake Michigan, and 100,000 pounds in United States waters of Lake Huron.

Round whitefish are known to eat the eggs of other fishes, lake trout in particular, but in turn its eggs and young are preyed upon by other species and itself is eaten by lake trout. It was considered an important forage fish for lake trout in Maine by Everhart (1958) and in Great Slave Lake by Rawson (1947).

Nomenclature

Salmo Cylindraceus	— Pallas (*in* Pennant 1784: ciii-civ) (type locality Lena, Kowyma, and Indigirska rivers)
Coregonus quadrilateralis	— Richardson 1823: 714

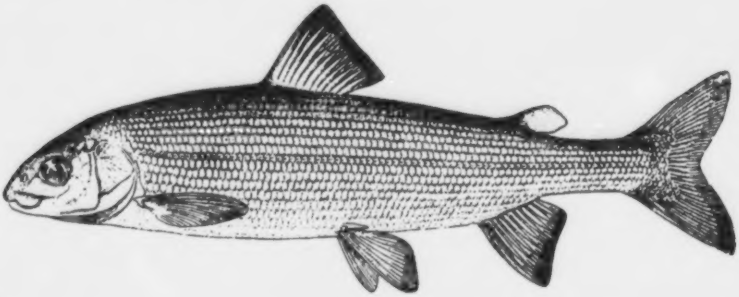
Salmo (Coregonus) quadrilateralis
(Richardson) — Richardson 1836: 204
Coregonus quadrilateralis Richardson — Cox 1896b: 67
Prosopium preblei — Harper and Nichols 1919: 266
Prosopium quadrilaterale Richardson — Hubbs 1926: 13
Prosopium quadrilaterale (Richardson) — Jordan, Evermann, and Clark 1930: 65
Prosopium cylindraceum (Pallas) — Dymond 1947: 8

Etymology *Prosopium* — a mask, from the large bones in front of the eyes; *cylindraceum* — like a cylinder.

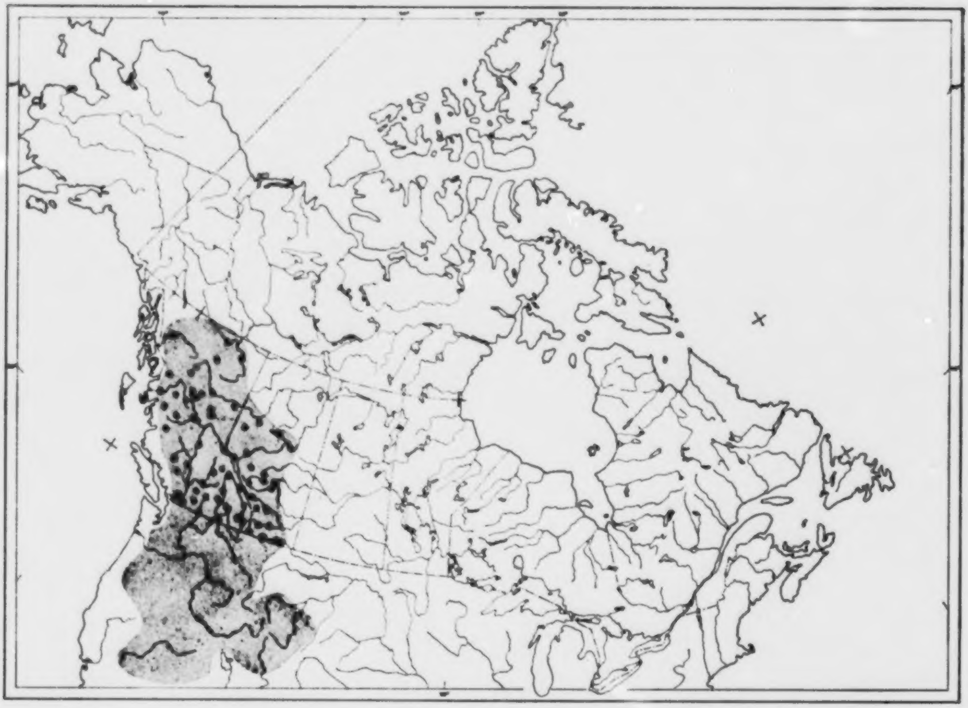
Common names Round whitefish, pilot fish, frost fish, round fish, round-fish, Menominee whitefish. French common name: *ménomini rond.*

MOUNTAIN WHITEFISH

Prosopium williamsoni (Girard)



Description Body slender, elongate, average length 8–12 inches (203–305 mm), body nearly cylindrical in cross section but variable, more compressed laterally than round whitefish, most young appear to be moderately compressed laterally. Head short, its length about 20% of total length; eye moderate, its diameter less than snout length; snout more or less pointed, compressed laterally, pinched, rounded in lateral view, a single flap of skin between nostrils; mouth small, ventral in position, overhung by snout; maxillaries extending posteriorly almost to anterior margin of eye of adults; teeth small, restricted to a small patch on tongue and on gill rakers of adults, although small teeth may be present on the premaxillae of young, but absent from jaws, vomer, palatines, and premaxillae of adults. Gill rakers short, total range 19–26, usually 8–11 on upper limb of gill arch, 11–15 on lower limb, gill rakers with teeth. Branchiostegal rays 7 + 7 to 10 + 10. Fins: small adipose dorsal present, rayed dorsal with 11–15 rays; caudal distinctly forked; anal rays 10–13; pelvic abdominal, 10–12 rays, a distinct pelvic axillary process present; pectoral rays 14–18, no pectoral axillary process. Scales cycloid, large, usually outlined with black or dark pigment; lateral line complete, 74–90



scales. Pyloric caeca variable, 50–146. Vertebrae 53–61. (*See also* Holt 1970 and Norden 1970.)

Nuptial tubercles developed on scales of sides of spawning males, very transitory according to Hagen (1970) but Vladykov (1970) presented figure showing development of tubercles on first 3 or 4 rows of scales above and below lateral line but not on head.

Colour Overall colouration silvery, but light or dark brown or olive on back, becoming silvery on sides and white below. Scales, especially on back, may have pigmented borders. Dorsal fin often dusky, pelvic and pectoral fins of adults with amber tint.

Young are silvery with two or more rows of black spots on sides; the lower row, arranged along the lateral line, consisting of eight to ten large, dark spots or parr marks, usually distinctly larger and more like typical salmonid parr marks than those on young round whitefish.

Systematic notes *Prosopium oregonium* was once considered to be a distinct species but Holt (1960) made a comparative morphometric and meristic study of the species and compared it with other members of the genus *Prosopium*. She concluded that *P. oregonium* was not distinct from *P. williamsoni* and presented considerable data on the species from various watersheds in support of her conclusions.

Distribution The mountain whitefish occurs only in the lakes and streams of western North America, from the Lahontan basin in Nevada, north through the northwestern states including Wyoming, Montana, and Idaho, to the Yukon–British Columbia border.

In Canada, it occurs in rivers and lakes of the foothill country of western Alberta from the Milk River north through headwaters of the South and North Saskatchewan rivers to the Peace River. It is widespread in British Columbia from the Fraser and Columbia River systems, throughout the Pacific coastal drainages of the Bella Coola, Skeena, Nass, and Stikine systems and inland in the Peace and Liard systems, attaining its northern limit in the latter.

Biology Spawning occurs in late fall or early winter over gravel or gravel and rubble, but the exact time of spawning varies throughout the range. No nest is prepared. The findings of different investigators are not in accord on such questions as whether lake-dwelling populations spawn on gravel shallows in lakes, or seek gravel beds in tributary streams, or whether spawning is activated by a falling temperature. Obviously, much remains to be learned about the spawning behaviour of this species. Lake spawning in Wyoming was reported by Hagen (1970) who also provided a review of times and places of spawning reported in the literature. In some areas at least, such as in Montana, spawning occurred from October to early November, at depths of 5 inches to 4 feet, and took place at night (Brown 1952). Night spawning was also reported for Kootenay Lake, where McPhail and Lindsey (1970) noted the presence of two or more types or races that may have spawned at different times and places, from October to February.

The eggs are relatively large and, when water-hardened, averaged 3.7 mm in diameter (Brown 1952). The number of eggs retained by females generally increases with increase in size. In a study of Montana females, Brown found egg numbers to vary from 1426 for a female 10.2 inches (259 mm) total length, to 7271 for one 17 inches (432 mm) long. A single female, 19.5 inches (495 mm) long, and weighing 48 ounces, twice the weight of the 17-inch fish, carried 24,143 eggs. Hagen (1970) gave a figure of 7757 eggs per pound of female. Most studies, however, indicate averages in the order of about 5000 eggs.

Development of eggs was described in detail by Brown (1952). In Montana, eggs deposited in late October or early November hatched in early March. Newly hatched fry could be found in stream shallows for a few weeks but at lengths of 1.2–1.6 inches (30–40 mm) they moved offshore.

Ages can be determined by scale examination. McHugh (1942) observed no difference in growth rates of males and females. There is, however, considerable variation in growth rate throughout the range, as indicated by the following table, modified from Northcote (1957), which shows the variation in average lengths for mountain whitefish populations in British Columbia, Alberta, Utah, and California.

Age at end of year	TL (*inches*)	TL (*mm*)
1	2.6–5.3	66–135
2	4.2–8.8	107–224
3	6.4–11.7	163–297
4	7.7–12.9	196–328
5	8.7–13.0	221–330
6	11.2–14.1	284–358
7	12.8–15.4	325–391
8	13.8–16.4	351–417
9	14.8–17.4	376–442

Fish become sexually mature at age 3 or 4. The maximum age attained appears to be 17 or 18 years in Bow Lake, Alta., reported by McHugh (1942). The largest mountain whitefish specimen known to the present authors is one reported by McPhail and Lindsey (1970) as the world's record. It was angled in Lardeau River, B.C., by R. A. Rutherglen, weighed 4 pounds 7 ounces (2013 g) and was 22.5 inches (572 mm) long.

The mountain whitefish inhabits lakes and larger rivers, apparently preferring large streams to small. It may inhabit small, turbid pools as well as cold, deep lakes, but tends to frequent the upper 15–20 feet (4.6–6.1 m) and seems seldom to occur below 65 feet (20 m). In the Skeena River system it was considered most abundant in shallow, eutrophic-type lakes. In Alberta, the ability of mountain whitefish to adapt to changing conditions, in this case hydro-electric development, was demonstrated by Nelson (1965).

It is primarily a bottom feeder consuming a variety of organisms, especially aquatic insect larvae such as those of mayflies, stoneflies, caddisflies, and midges, small molluscs, and, on occasion, fishes. A prickly sculpin was found in the stomach of a mountain whitefish caught in Kootenay Lake. When bottom fauna is scarce, mountain whitefish will eat midwater plankton and surface insects, but under these conditions, the species is usually less abundant (Godfrey 1955). Chironomids dominated the diet in Alberta reservoirs (Nelson 1965). Like most fishes adapted to bottom feeding, it will eat the eggs of its own and other species (Foerster 1925; Simon 1946) and although eggs of sockeye and coho have been recorded in stomach contents, it is doubtful that such activities are seriously detrimental to these fish. Ricker (1941) demonstrated that they will eat young fishes, for one specimen from among 53 examined from Cultus Lake, B.C., had 10 small sockeye in its stomach.

Mountain whitefish appear to have few predators (other than the universal one — man) but Godfrey established that in the Skeena Lakes, lake trout, and possibly burbot, will eat them. Like other round whitefishes, it will also eat its own eggs (Simon 1946). In some regions it competes with rainbow trout and salmon (*Oncorhynchus* spp.) since it eats the same kinds of food as these species.

Bangham and Adams (1954) examined 253 specimens of Rocky Mountain whitefish from 19 locations in the Columbia, Fraser, Skeena, and Peace River drainages and found 213 infected. The list of species is extensive; consult publication for details.

Hoffman (1967) listed approximately 30 species of parasites, involving trematodes, cestodes, nematodes, acanthocephalans, and crustaceans, but *see* publication for details.

Relation to man The mountain whitefish has been fished for food in many parts of British Columbia for many years. McHugh (1940) noted that before its sale was banned prior to 1940, it was even peddled from door to door. In recent years, it has gained popularity as a game fish in British Columbia and Alberta. It is fished by fly or with a small hook baited with stonefly larvae, salmon eggs, corn, or maggots. Fishermen sometimes call this whitefish "grayling", an unfortunate and erroneous local name.

Would-be anglers might enjoy a publication by John Gaffney (1960) on the utilization of mountain whitefish in Montana. Gaffney provided information on methods of fishing, where to fish, baits, preparation of catch including home smoking, and recipes for cooking whitefish.

The mountain whitefish has not been shown to be a serious predator on salmon or trout in Canadian waters (McHugh 1940; Godfrey 1955) although it does occasionally eat eggs and young of other species and may be a minor competitor for food in some areas.

Nomenclature

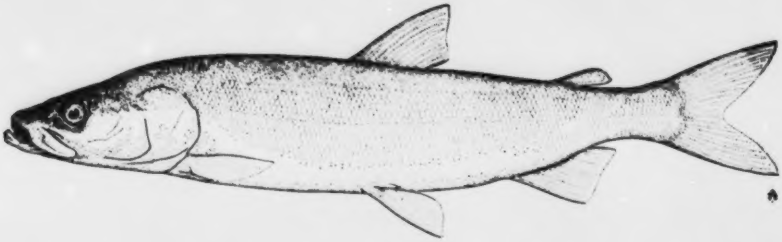
Coregonus williamsoni	— Girard 1856a: 136 (type locality Des Chutes R., Ore.)
Prosopium oregonium	— Dymond 1943: 201
Prosopium williamsoni (Girard)	— Dymond 1947: 8
	— Holt 1960: 192
	— Scott and Crossman 1969: 13

Etymology *Prosopium* — a mask, from the large bones in front of the eyes; *williamsoni* — after Lieut R. S. Williamson of the United States Pacific Railroad Exploration.

Common names Mountain whitefish, Rocky Mountain whitefish, Williamson's whitefish, grayling. French common name: *ménomini des montagnes*.

INCONNU

Stenodus leucichthys (Güldenstadt)



Description Body elongate, total length usually 18–30 inches (457–762 mm), only moderately compressed laterally, greatest body depth near tip of depressed pectoral fin, greatest body depth usually less than head length, 20–23% of total length. Head long, broad, shallow, its length 24–28% of total length; eye moderate to small, its diameter 20–22% of head length; snout distinctly longer than eye; mouth large, terminal, lower jaw obviously projecting beyond upper, maxillary extending to below middle of eye or beyond; small, fine teeth developed on anterior part of lower jaw, tongue, premaxillaries, head of maxillaries, vomer, and palatines. Gill rakers, range in total count 19–24 (6–9 on lower arm of gill arch). Branchiostegal rays 9–12. Fins: small dorsal adipose present; dorsal 1, high, pointed, rays 12–19; caudal distinctly forked; anal rays 15–18; pelvic rays 11, pelvic axillary process well developed; pectorals long, rays 16 or 17. Scales cycloid, large, 90–110 in lateral line. Pyloric caeca 150–202. Vertebrae 64–69.

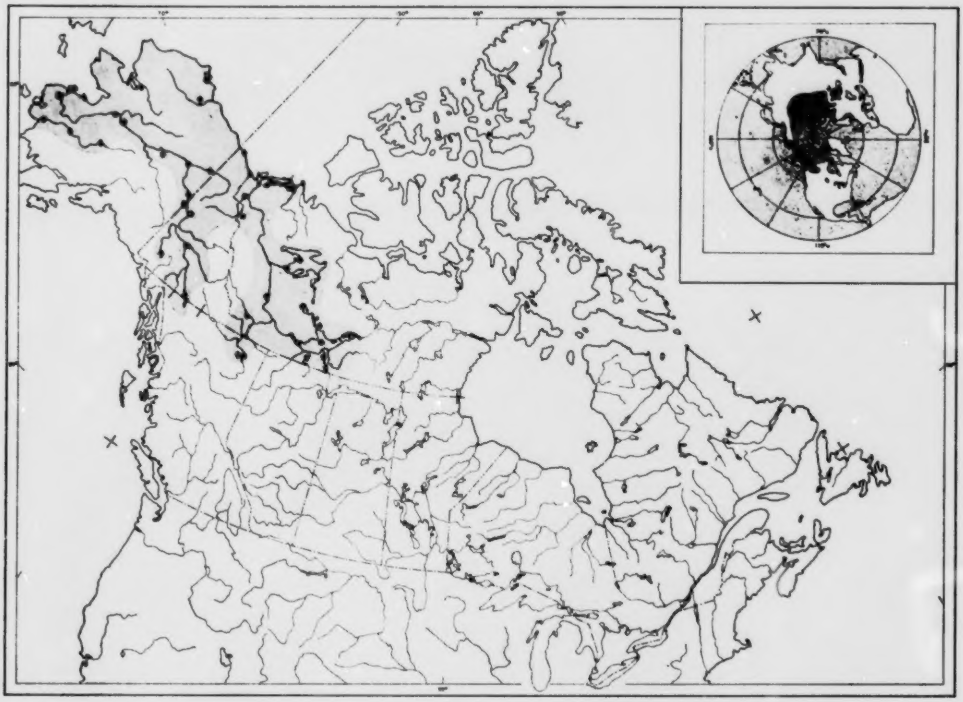
Nuptial tubercles or pearl organs not developed.

(*See also* Dymond 1943; McAllister 1962b; McPhail and Lindsey 1970.)

Colour Overall colouration silvery; usually green to pale brown on the back, especially when young, silvery on sides and silvery white below. Dorsal and caudal fins tipped with dark pigment, remaining fins clear or immaculate.

Systematic notes The species was described by Güldenstadt (1772) as *Salmo leucichthys* based on specimens from Caspian Sea drainages. The Siberian form was described by Pallas (1776) as *Salmo nelma* and the North American form by Richardson (1823) as *Salmo Mackenzii*. The North American form was generally known as *Stenodus mackenzii* until Dymond (1943) adopted Berg's (1932) view that the North American and Asian forms were conspecific and suggested that the North American form be designated *Stenodus l. mackenzii*. Walters (1955) and, later, Shaposhnikova (1967) demonstrated that the North American and Siberian forms were not subspecifically distinct and both should be referred to the subspecies *S. l. nelma*. The typical subspecies *S. l. leucichthys* is restricted to the Caspian Sea drainage.

Distribution The inconnu occurs in northwestern North America and west in the arctic drainages of northern Asia to the White Sea. An isolated population occurs in the northern Caspian Sea and its inflowing rivers. In North America, it ranges from the Kuskokwim River in the Bering Sea drainage of Alaska, north in coastal rivers to the Anderson River near Cape Bathurst, N.W.T.; in many parts of the Yukon River system to its headwaters (Teslin Lake), in southern Yukon Territory and northern British Columbia. It ranges through the Mackenzie River to Great Slave Lake and up the Slave River to



Fort Smith, and to Fort Nelson, B.C., on the Liard River.

Biology The biology of the inconnu has received more attention in Siberia than in Canada, and few recent studies of Canadian populations have been published.

Spawning probably occurs in late summer or early autumn in rivers, but there are no direct observations concerning behaviour during spawning or the kinds of spawning grounds used. It is suspected that individual fish spawn only once every 2, 3, or 4 years. In the Yenisei River, Siberia, Nikol'skii (1954) noted that egg number varied from 125,000 to 325,000 eggs. Although direct observations of spawning of Great Slave Lake populations have not been made, there are conspicuous downstream migrations following the time that spawning should take place, hence, it is considered that spawning probably occurs in those rivers having marked downstream runs in the fall of the year. Great Slave Lake rivers exhibiting such marked downstream runs are Big Buffalo and Taltson rivers, which have largest runs, and Slave, Little Buffalo, and Hay rivers with smaller runs. The upstream, presumably prespawning migration, is prolonged and apparently continues all summer.

Young inconnu are thought to remain in Big Buffalo River for at least 2 years before descending to Great Slave Lake. At about age 4 there was a marked acceleration of growth which Fuller (1955) thought might have been associated with a change in diet from benthos to fish. The rate of growth was fairly rapid, more rapid than that of the lake whitefish or lake trout, and Fuller reasoned this was so because the inconnu is an arctic fish at the southern part of its range, whereas the others are subarctic or temperate species at their northern limit.

The growth rate of Great Slave Lake fish is given in the following table (from Fuller):

Age (*years*)	SL (*inches*)	SL (*mm*)	Weight (*lb*)
1+	5.8	146	0.12
2+	9.7	247	0.44
3+	12.3	312	0.87
4+	15.9	403	1.62
5+	18.6	473	3.00
6+	20.8	529	4.36
7+	22.5	572	5.62
8+	24.0	610	7.13
9+	25.9	657	8.31
10+	27.1	688	9.75
11+	28.6	727	11.05

In Great Slave Lake inconnu mature in 7–10 years, but few live longer than 11 years, although Siberian fish live at least 21 years according to Nikol'skii (1954).

The inconnu grows to a larger size than any other whitefish species. One weighing "just over 63 pounds" and measuring 59.25 inches (1.5 m) long, was caught by K. H. Lang at the mouth of the Mackenzie River, July 12, 1936 (Dymond 1943). Lang reported, also, that he had seen several that weighed between 45 and 55 pounds, that 20–30-pound fish were common, but that the average weighed 6–12 pounds. In the Great Slave Lake drainage, the largest known fish weighed 55 pounds and was caught in Big Buffalo River about 1943; one weighing 54.7 pounds, and measuring 50 inches (1.27 m) fork length, was caught in Great Slave Lake in 1960 (Keleher 1961).

The inconnu is an anadromous species in coastal areas, ascending freshwater streams from the sea to spawn, but in inland lakes, such as Great Slave, it remains in fresh water throughout its life, migrating up tributary streams in summer, returning to the lake in late fall. These fall downstream runs are the spectacular ones and it is during this downstream run that inconnu are most readily caught.

The food of adults in Great Slave Lake consists almost entirely of small fishes, mainly young whitefishes but also northern pike, ninespine sticklebacks, young goldeye, minnows, arctic lamprey, and occasional small inconnu. (Dymond 1943; Rawson 1951; Fuller 1955.)

In the Yukon River, Alaska, inconnu also ate young chinook salmon, up to 16 per stomach in a study conducted by Alt (1965). Young inconnu eat aquatic insect larvae and planktonic crustaceans. Fuller concluded that inconnu changed from an invertebrate diet in rivers to a fish diet on entering Great Slave Lake and the adult phase of their lives.

Adult inconnu have few enemies except man, but Larkin (1945) reported that mature inconnu caught in the lower part of Big Buffalo River (Great Slave Lake) were gorged with young inconnu. Inconnu were also found in the stomachs of northern pike and burbot in Great Slave Lake (Rawson 1951).

The parasites harboured by the inconnu of Great Slave Lake were noted by Fuller (1955) who made particular mention of encysted *Triaenophorus crassus* in the muscle tissue. (*See Coregonus clupeaformis* for detailed account of *T. crassus*.) Other parasites reported by Fuller were *Proteocephalus* sp. and *Eubothrium* sp. in the intestine and *Salmincola* sp. on the gills.

Hoffman (1967) listed 8 trematodes, 5 cestodes, 2 nematodes, 1 leech, and 5 crustaceans that have been reported parasitic on inconnu in Soviet waters.

Relation to man Much has been written about the use of the inconnu for human and dog food by northern travellers. Its flesh is greatly appreciated by some but considered less than appetizing by others. Dymond (1943) quoted K. H. Lang, a local resident who fished the Mackenzie River in the vicinity of Aklavik, as follows: "It is a beautiful fish and in very much favour as human food, and also as dog food, although the smaller connie are a little dry and lean; but the bigger they are the fatter they get, and a piece of the tail of a big connie is generally considered the best feed of fish obtainable in the country." Richardson (1823) was less glowing in his praise and considered the inconnu "disagreeable when used as daily food." The palatability probably varies with the season and place of capture, as well as size of fish. For local use they are usually caught by gillnet, employed during the downstream runs in late autumn. The fish were usually split, and hung in the open air to dry, or were smoked. For additional information on local fisheries *see* Dymond (1943) and Melville (1914).

Commercially, Great Slave Lake inconnu are caught in gillnets. They are sold fresh or frozen, usually headless and dressed, at a wholesale price that fluctuates around 50 cents per pound. They are sold mainly on the United States market to be used in the smoked fish trade. Occasionally, they are offered for sale in major Canadian cities but a retail trade for fresh inconnu has not been developed. The oily flesh is probably better suited to smoking than to the fresh fish trade.

During the period 1953–1963, the commercial catch of inconnu from Great Slave Lake ranged from a low of 165,000 pounds in 1955 to a high of 344,000 pounds in 1963, but the catch appears to have fluctuated according to demand and not because of availability (Sinclair et al. 1967).

Some attention has been directed to inconnu as a sport or game fish, especially in Alaska, but Canadian stocks are seldom used by sportsmen. In a recent survey of fishing in Great Slave Lake, Keleher (1966) reported that, although stocks were adequate to support a commercial fishery, proper angling methods had not been discovered locally and, hence, a potentially valuable sport fishery was not being utilized.

Nomenclature

Salmo leucichthys	— Güldenstadt 1772: (type locality Caspian Sea drainages)
Salmo Mackenzii	— Richardson 1823: 707
Stenodus mackenzii (Richardson)	— Jordan and Evermann 1896–1900: 474
Stenodus leucichthys mackenzii (Richardson)	— Dymond 1943: 220
	— Carl and Clemens 1948: 39
Stenodus leucichthys nelma (Pallas)	— Carl, Clemens, and Lindsey 1967: 48
Stenodus leucichthys (Güldenstadt)	— Bailey et al. 1970: 17

Etymology *Stenodus* — narrow tooth; *leucichthys* — white fish.

Common names Inconnu, sheefish, connie, conny. French common name: *inconnu.*

Suggested Reading – subfamily Coregoninae

CHRISTIE, W. J. 1963. Effects of artificial propagation and the weather on recruitment in the Lake Ontario whitefish fishery. J. Fish. Res. Bd. Canada 20: 597–646.

CUCIN, D., and H. A. REGIER. 1965. Dynamics and exploitation of lake whitefish in southern Georgian Bay. J. Fish. Res. Bd. Canada 23: 221–274.

DEASON, H. J., and R. HILE. 1947. Age and growth of the kiyi, *Leucichthys kiyi* Koelz, in Lake Michigan. Trans. Amer. Fish. Soc. 74: 88–142.

DRYER, W. R., and J. BEIL. 1964. Life history of lake herring in Lake Superior. U.S. Fish Wildl. Serv. Fish. Bull. 63(3): 493–530.

DYMOND, J. R. 1943. The coregonine fishes of northwestern Canada. Trans. Roy. Can. Inst. 24: 171–231.

ESCHMEYER, P. H., and R. M. BAILEY. 1955. The pygmy whitefish, *Coregonus coulteri*, in Lake Superior. Trans. Amer. Fish. Soc. 84: 161–199.

FENDERSON, O. C. 1964. Evidence of sub-populations of lake whitefish, *Coregonus clupeaformis*, involving a dwarfed form. Trans. Amer. Fish. Soc. 93: 77–94.

FRY, F. E. J. 1937. The summer migration of the cisco, *Leucichthys artedi* (LeSueur), in Lake Nipissing, Ontario. Univ. Toronto Stud., Biol. Ser. 44, Publ. Ont. Fish. Res. Lab. 55: 91 p.

GODFREY, H. 1955. On the ecology of Skeena River whitefishes, *Coregonus* and *Prosopium*. J. Fish. Res. Bd. Canada 12: 499–541.

HART, J. L. 1930. The spawning and early life history of the whitefish, *Coregonus clupeaformis* (Mitchill), in the Bay of Quinte, Ontario. Contrib. Can. Biol. Fish. 6(7): 165–214.

HILE, R. 1937. Morphometry of the cisco, *Leucichthys artedi* (LeSueur), in the lakes of the northeastern highlands, Wisconsin. Sonderdr. aus: Int. Rev. Hydrob. Hydrog. Leipzig 36(1/2): 57–130.

JOBES, F. W. 1949. The age, growth, and distribution of the longjaw cisco, *Leucichthys alpenae* Koelz, in Lake Michigan. Trans. Amer. Fish. Soc. 76: 215–247.

KENNEDY, W. A. 1943. The whitefish, *Coregonus clupeaformis* (Mitchill), of Lake Opeongo, Algonquin Park, Ontario. Univ. Toronto Stud., Biol. Ser. 51, Publ. Ont. Fish. Res. Lab. 62: 21–66.

KOELZ, W. 1929. Coregonid fishes of the Great Lakes. Bull. U.S. Bur. Fish. (1927–28) 43: 297–643.

1931. The coregonid fishes of northeastern America. Pap. Mich. Acad. Sci. Arts Lett. 13: 303–432.

LAWLER, G. H. 1965. Fluctuations in the success of year-classes of whitefish populations with special reference to Lake Erie. J. Fish. Res. Bd. Canada 22: 1197–1227.

LINDSEY, C. C., and C. S. WOODS [ed.] 1970. Biology of coregonid fishes. University of Manitoba Press, Winnipeg, Man. 560 p.

MCPHAIL, J. D. 1966. The *Coregonus autumnalis* complex in Alaska and northwestern Canada. J. Fish. Res. Bd. Canada 23: 141–148.

NORMANDEAU, D. A. 1969. Life history and ecology of the round whitefish *Prosopium cylindraceum* (Pallas), of Newfound Lake, Bristol, New Hampshire. Trans. Amer. Fish. Soc. 98: 7–13.

PRITCHARD, A. L. 1931. Taxonomic and life history studies of the ciscoes of Lake Ontario. Univ. Toronto Stud., Biol. Ser. 35, Publ. Ont. Fish. Res. Lab. 41: 78 p.

SCOTT, W. B. 1951. Fluctuations in abundance of the Lake Erie cisco (*Leucichthys artedi*) population. Contrib. Roy. Ont. Mus. Zool. 32: 41 p.

SMITH, S. H. 1964. Status of the deepwater cisco population of Lake Michigan. Trans. Amer. Fish. Soc. 93: 155–163.

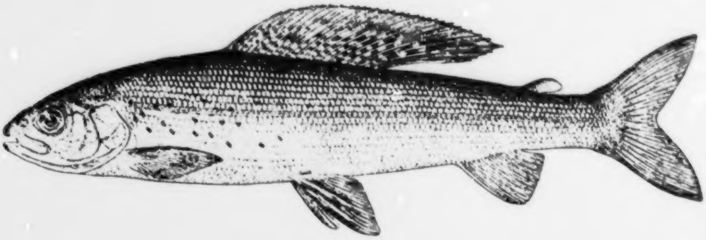
VAN OOSTEN, J. 1929. Life history of the lake herring (*Leucichthys artedi* LeSueur) of Lake Huron as revealed by its scales, with a critique of the scale method. Bull. U.S. Bur. Fish. (1928) 44: 265–428.

1939. The age, growth, sexual maturity, and sex ratio of the common whitefish, *Coregonus clupeaformis* (Mitchill), of Lake Huron. Pap. Mich. Acad. Sci. Arts Lett. 24: 195–221.

Subfamily Thymallinae Graylings, without orbitosphenoid, hypethmoid, suprapreopercle, or basibranchial plate; maxilla and premaxilla with teeth; with dermosphenotic and epipleurals; parietals meet at midline; scales, embedded margins indented; 17 or more dorsal fin rays; eggs small, a postlarval stage, young with parr marks.

ARCTIC GRAYLING

Thymallus arcticus (Pallas)



Description Body elongate, laterally compressed, troutlike, cross section a long oval, average length 12–15 inches (305–381 mm), greatest body depth near dorsal fin origin 18.0–20.2% of total length; caudal peduncle long and slender. Head short, 16–17% of total length, shallow, narrow; eye rather large, diameter 22.5–25.7% of head length, about equal to snout length; snout short, 21.6–25.2% of head length; mouth moderate, premaxillaries nonprotractile; lower jaw sometimes longer than upper; maxillary moderate, extending only to middle of pupil, rather wide; teeth rather small, on both jaws (premaxillary, maxillary, dentary), tongue (sometimes absent in adults), head of vomer (few), palatines, no basibranchial (= hyoid) teeth (Atton, personal communication reported tooth sockets on basihyal); a few small pharyngeal teeth. Gill rakers of moderate size, usually 16–23, usually 5–7 on upper limb and 11–15 on lower limb. Branchiostegal rays 7–9. Fins: dorsal adipose present; dorsal 1, the large size of this fin, especially in males is its most striking feature, base long, usually equal to or longer than head, fin very high, posterior rays greatly lengthened, vividly coloured, 17–25 total rays, depressed fin of mature males reaching to or beyond adipose fin, shorter in females, fin of male highest at back, that of female highest at front; caudal broad, deeply forked, tips pointed, lower lobe sometimes longer; anal rather small, edge square, 11–15 total rays; pelvics abdominal, under centre of dorsal fin, axillary process small, fin long, in mature males reaching almost to anus, shorter in females, broad, edge square, vividly coloured, 10 or 11 rays; pectorals low, long, rather pointed, 14–16 rays. Scales cycloid, moderately large (*see* Miller 1946b, for photos); lateral line complete, straight, 77–98 pored lateral line scales according to McPhail and Lindsey (1970) but Atton (personal communication) recorded 81–103 in material from Northwest Territories. Pyloric caeca 14–21. Vertebrae 58–62. Norden (1961a) gave extensive details of the osteology of this species and compared the grayling with other salmonoid fishes. Ward

(1951) gave counts and measurements for grayling in the Athabasca River in Alberta.

No nuptial tubercles and none of the body changes so characteristic of salmonids at spawning time, but colours darken and the males become more brilliant than the females.

Colour A strikingly coloured fish, the dorsal surface is dark purple, or blue-black to blue-grey, the sides are grey to dark blue with a pinkish iridescence, the ventral surface grey to white. The sides are marked with a varying number of V-shaped or diamond-shaped spots, mostly ahead of the pelvic fins (more on young), and a dark stripe between the paired fins. The head is olive-green with a mauve iridescence, black on the base of the branchiostegal rays and the eye is dark green and gold. The dorsal fin is basically black with a narrow, mauve edge, often with a wider blue band below, and vertical rows of orange-red or mauve to emerald green spots, largest at the top and on the long, flexible, posterior lobe. The adipose, caudal, anal, and pectoral fins are dusky to bronze. The pelvic fins are black and crossed on an angle (not vertical between the rays) by wavy, mauve or orange lines. Females are similarly but less brightly marked.

The young are deeper than most salmonids, greenish above with a large dorsal, 10–20 dark parr marks straddling the lateral line, and small, black spots or dark broken lines above them.

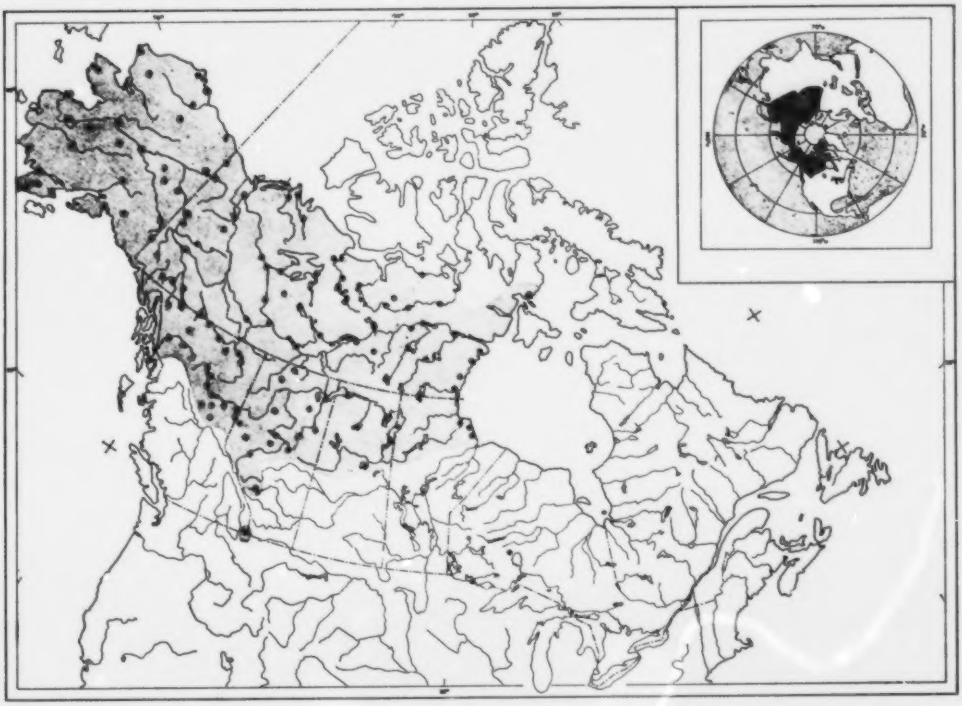
Systematic notes The graylings were, until recently, placed in a separate family, Thymallidae, and some authors still do so. There are four species, *T. brevirostris* (Mongolia), *T. thymallus* (Britain to central Europe), *T. nigrescens* (Lake Kosogol, Mongolia) and *T. arcticus* (with several subspecies — western Siberia and North America). At one time in North America there were three or four isolated stocks which were referred to as separate species, *T. signifer* Richardson (Alaska and northern Canada), *T. montanus* Milner (Upper Missouri River), *T. tricolor* Cope (Upper Great Lakes tributaries in Michigan, now extinct), and two specimens named *T. ontariensis* Cuvier and Valenciennes, thought to have come from the Great Lakes but generally presumed to have erroneous locality data. Walters (1955) considered *T. signifer* synonymous with *T. arcticus* and the others as subspecies of it. The validity of the subspecies distinctions in North America has not been adequately demonstrated.

Confusion may exist as the mountain whitefish is called grayling in certain northwestern areas.

Distribution The arctic grayling has a holarctic distribution and occurs in northern freshwater drainages (and, rarely, in salt water in Asia) from Hudson Bay west including all of Alaska, St. Lawrence Island, Bering Sea, to the Kara and Ob rivers of northern Eurasia. It extends south in Asia to northern Mongolia and the Upper Yalu River. Grayling occur in the headwaters of the Missouri River above Great Falls, Mont., and populations there have been maintained by fish culture and introduction from Canada. A population that once existed in rivers flowing into lakes Michigan, Huron, and Superior in northern Michigan, disappeared about 1936 even after introductions from Montana into the original habitat and elsewhere in Michigan. They have been introduced into the mountainous areas of such states as Vermont, Utah, and Colorado.

Arctic grayling occur in Canada from Vansittart Island off Melville Peninsula south along the west coast of Hudson Bay to the Owl River, Man., west throughout the Northwest and Yukon territories (excluding other arctic islands), south in Saskatchewan to Reindeer Lake but absent from much of the Churchill River, south to central Alberta and in northern British Columbia from the Peace and Stikine rivers north. They also occur in extreme southeastern British Columbia in the Flathead River, and southwestern Alberta in the Belly River, having spread there from Montana. *See* Fowler (1948), Rawson (1950), Carl et al. (1967), Paetz and Nelson (1970), and McPhail and Lindsey (1970) for more detail.

In 1959 thousands of yearling to 4-year-old grayling were stocked in 16 rivers



and lakes in Thunder Bay, Kenora, Geraldton, and Nipissing districts of Ontario. The museum has four specimens 13.7–15.7 inches (350–400 mm) from Blue Lake, Thunder Bay District, taken in 1961. It is presently considered, however, that there are no grayling in Ontario. Over a 10-year period, 10 million grayling fry were stocked in Lac la Ronge, Sask. They are reported to be established in one inflowing river. The species has been established in several small Saskatchewan lakes.

Biology Grayling spawn during that period in which the ice is first breaking up in the smaller streams. This varies over their subarctic to arctic habitat from April to June, and possibly later in some years. Spawning has been described by Rawson (1950) and Bishop (1971) for Reindeer River, Sask., and for Great Slave Lake. As the ice is breaking up in the small streams, adults migrate from ice-covered lakes and from larger rivers to small gravel- or rock-bottomed tributaries. Where there are no suitable small streams spawning takes place in gravelly to rocky parts of the main rivers. In Alaska spawning sometimes occurs in mud-bottomed vegetated pools below rapids. The run usually overlaps, or follows immediately after, that of northern pike, when water temperatures are 44.6°–50.0° F (7°–10° C). The males are territorial on the spawning grounds, chase intruding small males. If the male is another spawner there is a characteristic lateral threat display involving raised dorsal fin, extended pelvic fins, gaping mouth, lowered branchiostegals to display the black patch, and rapid vibration while swimming toward the surface. There is no spawning at night and it is most active during warmer water temperatures of midday. No actual nest or redd is prepared. During spawning the male curves the extended dorsal fin over the female almost like a clasping organ, the female gapes, there is vigorous vibration, the male gapes, sex products are discharged and somewhat covered by the material stirred up during vibration. The female may spawn once only, or several times in different areas. After spawning, adults return to the lakes or rivers.

Egg number per female in Great Slave Lake, by volumetric estimate, ranged from 6120–15,905 for fish 10–17 inches (254–432 mm) fork length and 24.5–45.0 ounces weight. Average number is probably 4000–7000. Egg size in the ovary is about 2.5 mm. Size after different periods of water hardening has been given as 2.7 mm (Bishop 1971) and as 6/inch = 4.3 mm (Rawson 1950). The eggs are amber, demersal, and apparently adhesive for only a short time. No parental care is given eggs or young. Hatching takes place rather quickly for the area and temperature, 13–18 days at 44.6°–51.8° F (7°–11° C). Early development of grayling in Montana was discussed in detail by Watling and Brown (1955). The young are only about 8 mm long when hatched and spend another 8 days absorbing the yolk but apparently take food 3 days after hatching. Growth is rapid at first. Young-of-the-year in Nueltin Lake, N.W.T., were 2½ inches (64 mm) long by late August (Harper 1948) but were without scales. Growth in later years is variable with latitude and temperature, slower farther north. Age can be determined by scales and size at previous annuli back calculated (Miller 1946b). The table below gives age–length relation for various habitats. *See* Reed (1964) for summary of growth in various types of Alaskan habitats.

Some males and females reach sexual maturity at 4 years of age but the largest percentage (93.5%) of spawners are 6–9 years of age in Great Slave Lake. Most spawning fish over 9 years of age are females. Spawners in Reindeer River are mostly 5 and 6 years old, 16–20 inches (406–508 mm) long and weigh 2.1–3.8 pounds. Adults spawn several times but possibly not all of them every year. Maximum age would appear to be 11 or 12 years. Maximum known size in Canada and present angler record is that of a grayling 29⅞ inches (757 mm) long (fork length?), 15⅛ inches (385 mm) in girth, and 5 pounds, 15 ounces in weight. It was caught in the Katseyedie River, N.W.T., in 1967. A specimen 5 pounds, 7 ounces and 21 inches (530 mm) long caught in Great Bear Lake was the previous record.

The general habitat of the grayling is the clear waters of large, cold rivers, rocky creeks, and lakes. They live in bog-fed areas in some parts of Alaska. In some areas in summer, they apparently inhabit lakes, and in others, streams. They avoid turbid parts of the Mackenzie River but enter milky, glacial streams. In other areas they move into large rivers during freeze-up. Reed (1964), as well as giving their life history, gave details of physical and chemical characteristics of their habitats in Alaska. Grayling are usually associated with Pacific salmons; lake, rainbow, and cutthroat trouts; Dolly Varden; inconnu, and other whitefishes; and northern pike. In gillnet sets in Great Slave Lake, grayling were taken only to 10 foot (3.05 m) depth.

Food of the young is mainly zooplankton with a gradual shift to immature insects, mainly mayflies, caddisflies, and midges, with increase in size. The adults consume a very broad assortment of invertebrates but mainly aquatic and terrestrial insects, including those mentioned, bees, wasps, grasshoppers, ants and a variety of beetles. Other items eaten

		Age								
	FL	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
L. Athabasca, Sask.	*inches*	4.4	7.5	10.0	12.0	13.7	14.8	–	–	–
(Miller 1946b)	*mm*	112	191	254	304	349	375	–	–	–
Prairie Creek, Alta.	*inches*	4.3	6.7	8.9	10.6	11.8	12.4	12.8	–	–
(Ward 1951)	*mm*	109	171	226	269	300	316	326	–	–
Great Bear L., N.W.T.	*inches*	3.7	6.1	9.1	11.2	12.8	13.9	14.9	15.7	16.2
(Miller 1946b)	*mm*	93	155	231	285	325	353	378	399	410
Little Salcha R., Alaska	*inches*	3.6	5.3	7.5	9.1	10.8	11.4	12.0	–	–
(Wojcik 1956)	*mm*	90	135	189	232	274	289	304	–	–

are small quantities of fishes (grayling and cisco) fish eggs, lemmings, and plankton crustaceans (Miller 1946b). Food was analyzed in great detail for several areas in northern Saskatchewan by Rawson (1950).

Very little is known of the predators of the grayling. Other fishes and predatory birds such as eagles, osprey, gulls, and mammals such as mink and otter, probably prey on the young and smaller adults. Grayling, as a result of the quantity of terrestrial insects taken at the surface, do not constitute serious competitors of other fishes. Their ease of capture, late maturity and slow growth, and need for clear, cold, unpolluted water endanger them in populous areas.

Parasites reported for this species from Great Bear Lake by Miller (1946b) were the cestodes *Triaenophorus crassus*, *T. nodulosus*, and *Cyathocephalus* sp.; unidentified nematodes; the acanthocephalan *Echinorhynchus coregoni*; and the copepod *Salmincola thymalli*. Bangham and Adams (1954) added the trematode *Crepidostomum* sp., and the nematode *Metabronema* from the Peace River in British Columbia. Hoffman (1967), who listed parasites of grayling from North America, Russia, and Iceland, added the trematodes *Tetraonchus alaskensis* and *T. rauschi*.

In 1969 Schmidt reported a new species of acanthocephalan, *Paracanthocephalus rauschi*, from this species on St. Lawrence Island, Bering Sea.

Relation to man This species has been taken by Eskimos and Indians in the past in moderately large numbers as food for their dogs and, less often, for themselves. This was usually done only when trout and whitefishes were scarce. Miller (1947) reported that one Franklin Indian on Great Bear Lake took as many as 22,000 in 1 year. These were taken in June in stream traps and dried. Otherwise the relationship is an aesthetic one. The beautiful fish is a joy to behold and one of the few species over much of the northern part of Canada that will provide fly fishing. The preponderance of surface insects in the food, their habit of testing almost everything on the surface of the water, their schooling habit and tendency to leap when hooked, make them an attractive sport fish. Anglers also catch them with natural bait and a variety of small spinning lures. In such places as the Bear River near Fort Franklin, Great Bear Lake, they can be readily caught in fair numbers averaging 12–16 inches (305–406 mm) and 1–2 pounds weight. Fly fishermen are willing to pay considerable fees to fly into northern Canadian areas to catch this beautiful fish, which occurs in abundance only there.

Nomenclature

Salmo arcticus — Pallas 1776: 35 (type locality Ob River, Siberia)
Coregonus Signifer — Richardson 1823: 711
Coregonus Thymalloides — Richardson 1823: 714
Salmo (Thymallus) signifer (Richardson) — Richardson 1836: 190
Salmo (Thymallus) thymalloides (Richardson) — Richardson 1836: 194
Thymalus ontariensis — Cuvier and Valenciennes 1848: 452
Thymallus tricolor — Cope 1865: 80
Thymallus Pallasii — Dall 1870: 579
Thymallus montanus — Milner 1874: 741
Thymallus signifer — Günther 1866: 202
Thymallus tricolor montanus Milner — Whitehouse 1919: 52
Thymallus arcticus pallasi Valenciennes — Berg 1936: 58
Thymallus signifer tricolor Cope — Hubbs and Lagler 1947: 44
Thymallus arcticus — Wynne-Edwards 1952: 16
Thymallus arcticus signifer (Richardson) — Walters 1955: 290
Thymallus arcticus (Pallas) — Scott 1958: 10

Etymology *Thymallus* — thyme-like, referring to its supposed odour like that of the herb thyme; *arcticus* — of the arctic.

Common names Arctic grayling, grayling, American grayling, bluefish, Back's grayling, sailfin arctic grayling, arctic trout, tittimeg, poisson bleu (of the voyageurs). French common name: *ombre arctique.*

Suggested Reading – subfamily Thymallinae

FABRICIUS, E., and K.-J. GUSTAFSON. 1955. Observations on the spawning behaviour of the grayling, *Thymallus thymallus* (L.). Rep. Inst. Freshwater Res. Drottningholm 36: 75–103.

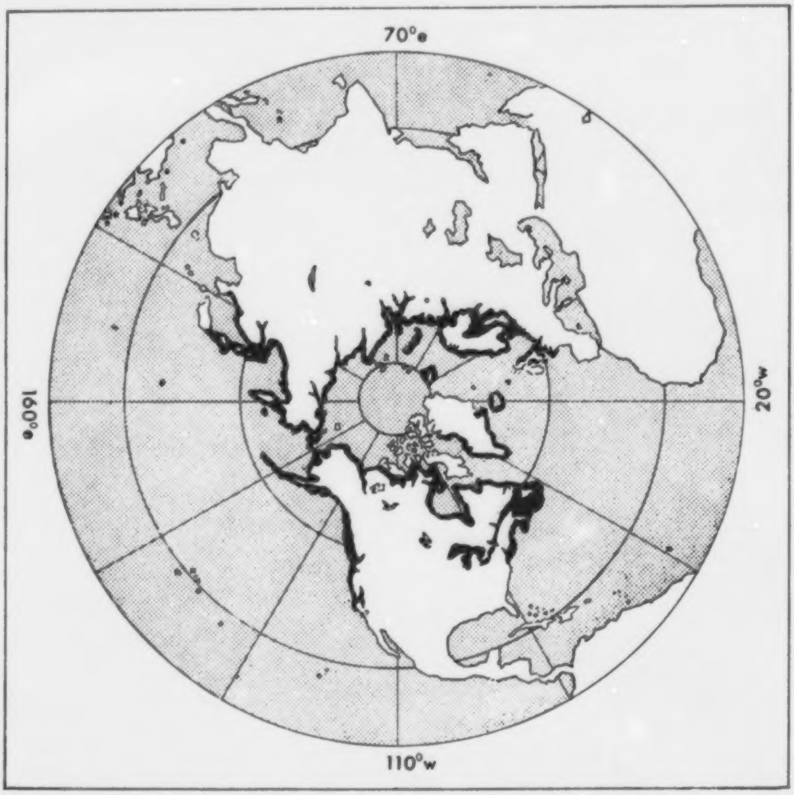
KRUSE, T. E. 1959. Grayling of Grebe Lake, Yellowstone National Park, Wyoming. U.S. Fish Wildl. Serv. Fish. Bull. 149, vol. 59: 307–351.

NORDEN, C. R. 1961. Comparative osteology of representative salmonid fishes, with particular reference to the grayling (*Thymallus arcticus*) and its phylogeny. J. Fish. Res. Bd. Canada 18: 679–791.

SMELT FAMILY — Osmeridae

Small, slender, silvery fishes, with elongate, laterally compressed bodies and large mouths. Teeth well developed (*Osmerus*) or weakly developed (*Mallotus*), on mesopterygoid, glossohyal, vomer, palatines, premaxillary, maxillary, and dentary. Branchiostegals 6–10. Adipose fin present. Scales, thin, cycloid, confined to body; lateral line present; pelvic axillary scale absent. Pyloric caeca 11, or 1 minute, or absent. Vertebrae 50–77; only urostylar vertebra is upturned and is not included in total count.

The smelts are circumpolar fishes, restricted to the northern hemisphere. They may be marine, anadromous, or freshwater in habit in Atlantic, Arctic, or Pacific oceans and their drainages. The family includes 6 genera and 10 species, but only 4 genera and species occur in Canadian fresh waters.



World Distribution of the Smelts

KEY TO SPECIES

1 Gill rakers on upper half of arch 4–6; pyloric caeca 8–12; scales in lateral line 70–86, lateral line complete; pronounced concentric marks on operculum .... EULACHON, *Thaleichthys pacificus* (p. 320)

Gill rakers on upper half of arch 8–14; pyloric caeca 0–11; scales in lateral line 65 and fewer, lateral line incomplete; no obvious concentric marks on operculum 2

2 Maxillary extending only to middle of pupil; tongue teeth minute and villiform; pyloric caeca 0–4; snout somewhat rounded; rarely over 6 inches (150 mm) .... POND SMELT, *Hypomesus olidus* (p. 308)

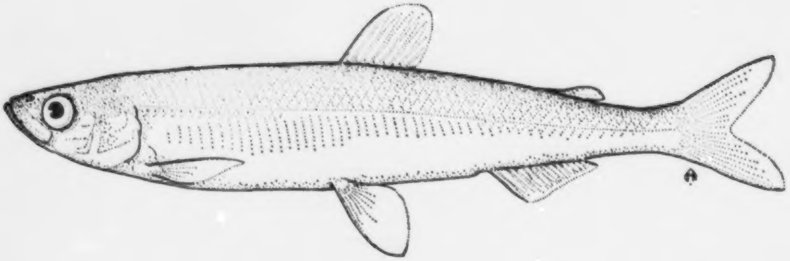
Maxillary extending beyond pupil, usually to posterior margin of eye; tongue teeth from small conical to large canine; pyloric caeca 4–11; snout more pointed; size larger 3

3 Gill rakers on lower half of arch 27–34, total gill rakers usually 37–47; anal rays usually 15–19; base of anal fin more than 3 times eye diameter; no enlarged teeth on tongue; rarely over 6 inches (150 mm) .... LONGFIN SMELT, *Spirinchus thaleichthys* (p. 318)

Gill rakers on lower half of arch 18–24, total gill rakers usually under 37; anal rays usually fewer than 16; base of anal fin about 2.5 times eye diameter; 1 or 2 prominent, curved, canine teeth on tip of tongue larger; size large, to 12.8 inches (324 mm) .... RAINBOW SMELT, *Osmerus mordax* (p. 310)

POND SMELT

Hypomesus olidus (Pallas)

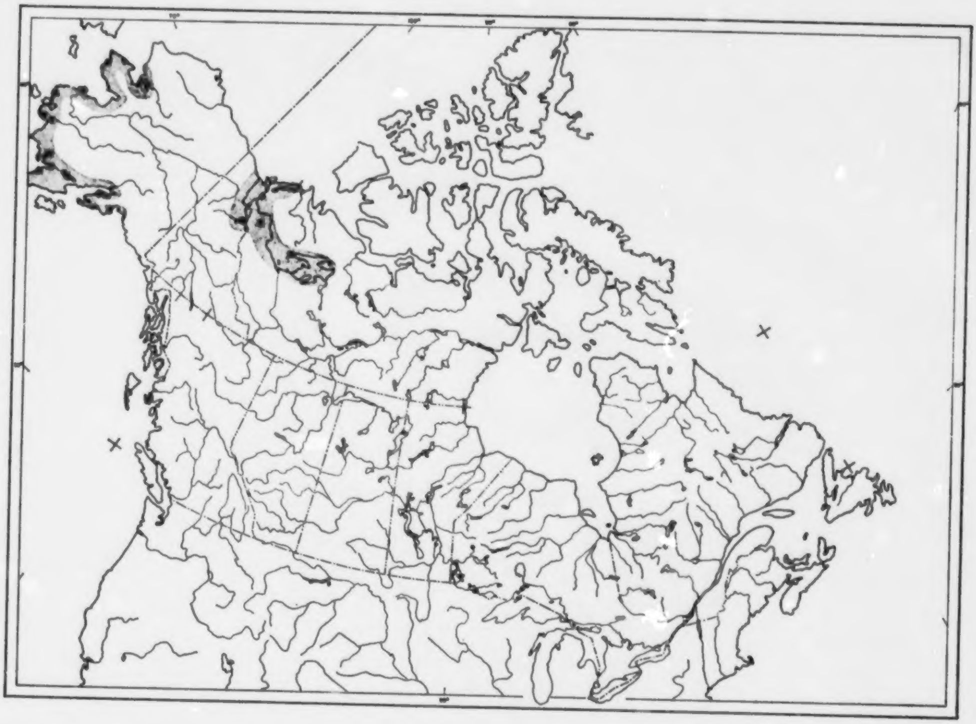


Description Body robust, subcylindrical in cross section, somewhat laterally compressed, greatest depth, at origin of dorsal fin, 15.8–23.8% of scaled or standard length of body; usually about 6 inches (150 mm) in total length. Head moderately long, 20–25% of standard length; eye moderately large, diameter 20.4–30.3% of head length; snout short, bluntly pointed; mouth small, oblique, maxillary extends to anterior edge or middle of pupil; small, pointed teeth on vomer, palatine, mesopterygoid, pharyngeal plates, basibranchial, dentary, maxillary, premaxillary, and tongue, but none enlarged. Gill rakers 26–34 (8–12 + 17–22), long and slender. Branchiostegal rays 6–8. Fins: single, soft-rayed dorsal fin at middle of body, 7–9 principal rays, upper edge slightly rounded; adipose present, low, its base 90–120% of eye diameter; caudal well forked and with 19 principal rays; caudal peduncle narrow and moderately long; anal with long base, edge slightly crescentric, 12–18 (usually 12–16) principal rays, longest ray 43.4–55.5% of head length; pelvics inserted below or ahead of origin of dorsal fin, with 8 rays, tip rounded, reach almost to anus in mature males, shorter in females; pectorals shorter than head, thoracic, low, with 10–12 or 13 rays. Scales large, cycloid, 51–62 in midlateral series; lateral line incomplete, extending less than head length along body, with 7–16 pored scales; pyloric caeca usually 2 in North America but 0–4 over whole range; physostomous, duct attaches behind anterior end of swim bladder. Vertebrae 51–62. There are well-developed tubercles on the scales, head and fins of spawning males, weak or usually absent on females. (McAllister 1963; McPhail and Lindsey 1970).

Colour Adults light brown to olive-green on the back, a metallic silver band along midlateral line (less pronounced in young), ventral surface silver-white; fins immaculate. Speckling along border of dorsal scales, a stripe on peduncle, snout and operculum. The peritoneum is light and slightly speckled (McPhail and Lindsay 1970; McAllister 1963).

Systematic notes Often divided into subspecies, the variability within populations of characters used to separate the subspecies shows that this is not warranted. This species has been confused with the two others in the genus, creating confusion in the literature. Populations in California recorded as *H. olidus* were described as a new species, *H. transpacificus*. Much of the Japanese literature prior to 1963 referring to this species probably pertained to *H. transpacificus nipponensis* (McAllister 1963).

Distribution The pond smelt occurs in eastern Asia, Japan, Korea, and northwestern North America. In Asia it extends from Wonsan, Korea, north to the Alazeya River, Siberia, Hokkaido, and Sakhalin. An isolated



population occurs in Lake Kugloe in the Kara Sea drainage of the USSR. In North America it is known from the Copper River north to the Kobuk River in Alaska: the Peel River, Yukon Territory, and the Mackenzie River from Inuvik to Great Bear Lake.

There is a gap of 1700 miles between the isolated population in Lake Kugloe and the nearest population in the Alazeya River, Siberia (McAllister 1963).

Biology Spawning occurs in streams in April or May in Asia, but Alaskan specimens were taken in spawning condition in early to late June. Spawning takes place in littoral areas over bottoms covered with organic debris. Jordan and Evermann (1896–1900) recorded the pond smelt as spawning in freshwater ponds. Some spawning may occur in streams in Alaska also. Eggs are adhesive and hatch in about 18 days at 50° F (10° C) in Black Lake, Alaska. By September the young pond smelt are about 1.2 inches (30 mm) long, at 1 year they are 2.4 inches (60 mm) long, and 3.2 inches (80 mm) long at 2 years of age. Very few live longer than the third year (McPhail and Lindsey 1970).

The largest specimens seen by McAllister (1963) were 4 inches (102 mm) long, but he cited Russian records up to 7.3 inches (185 mm).

In arctic North America this is a wholly freshwater species, unlike others in the genus, which are marine or euryhaline. McAllister (1963) suggested that it ventures into brackish water farther to the south. The pond smelt lives in lakes and streams.

Sato (1952) gave the food of young-of-the-year as rotifers and that of older and larger individuals as made up of rotifers, algae, insects, and crustaceans in varying amounts in different seasons. Sato was probably referring to *H. transpacificus*, but the diet of *H. olidus* in similar waters is probably the same.

McPhail and Lindsey (1970) claimed this species had no predators in Black Lake, Alaska, but that, as pelagic feeders, they may be significant competitors of juvenile sockeye salmon.

Relation to man Jordan and Evermann (1896–1900), probably quoting Turner (1886), said that the pond smelt was excessively abundant around St. Michael, Alaska, and that it was a sweet fish, excellent as food.

Turner (1886) had said that by May 20 in 1887 this species so filled a half-acre lake near St. Michael, Alaska, that the natives gathered thousands by simply throwing them out with a stick, and that a dipnet thrust would yield 2 or 3 gallons. He said when fried they were sweet and excellent eating and that the natives dried them on strings of grass. They are small but are probably used as food by local people wherever they are abundant, especially in Japan and Korea. They are not a commercial species in North America.

Nomenclature

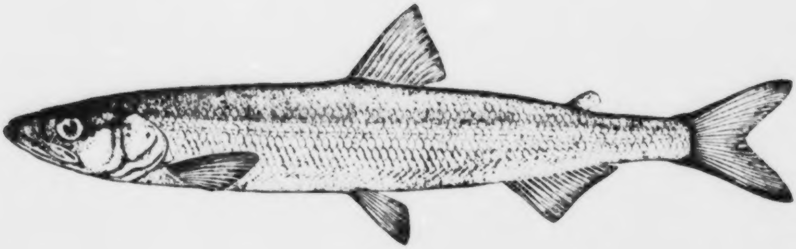
Salmo (Osmerus) olidus	— Pallas 1814: 39 (type locality Kamchatka)
Mesopus olidus	— Günther 1866: 169
Hypomesus olidus	— Jordan and Gilbert 1883a: 295

Etymology *Hypomesus* — below the middle, referring to the position of the pelvic fins; *olidus* — oily.

Common names Pond smelt, *malorotaya korioshka* in Russian, and *ishikari-wakasagi* in Japanese. French common name: *éperlan à petite bouche.*

RAINBOW SMELT

Osmerus mordax (Mitchill)



Description Body elongate, average length 7–8 inches (178–203 mm), laterally compressed, greatest depth anterior to dorsal fin origin, 12.6–13.8% of standard length. Head moderately long, its length 19.0–19.7% of standard length; eye moderately large, its diameter 17.5–24.0% of head length; snout elongate, pointed; mouth large, lower jaw protruding, maxillary extends to middle of eye or beyond, well toothed on vomer, palatine, pterygoid, basibranchial, dentary, maxillary, premaxillary, and tongue, teeth especially enlarged on tongue and front of vomer. Gill rakers 8–11 + 18–24, long, slender. Branchiostegal rays usually 7,7, but may be 5,7; 6,5; 6,6; 6,7; 7,6. Fins: dorsal 1, soft rayed, located at midbody, its origin over origin of pelvic fins, 8–11 rays; adipose present and well developed, its base 50.0–79.4% of eye diameter; caudal forked, with 19 rays; anal base long, rays 12–16, usually 13–15, longest ray 37.1–44.4% of head length; pelvics abdominal, fanlike, inserted below dorsal fin origin, 8 rays; pectorals shorter than head, low on sides, 11–14 rays. Scales cycloid, thin, deciduous, 62–72 in lateral series, perforate scales in lateral line 13–30, usually 14–28; lateral line incomplete. Peritoneum silvery with dark speckles; intestine short, pyloric caeca 4–8. Vertebrae 58–70, usually 60–66.

Nuptial tubercles small, like sandpaper to the touch, extensively developed over head, body and fins of males; seldom on females (*see* McKenzie 1964).

For additional data, *see* McAllister (1963), McPhail and Lindsey (1970).

Colour The rainbow smelt is a slender, silver fish, pale green on back, but with purple, blue, and pink iridescent reflections on the sides when freshly caught. Spawning males usually have small tubercles profusely distributed over the head and body and often do not show as colourful reflections as the females, although they are just as colourful when the nuptial tubercles are lost. The fins are generally clear. Populations of landlocked smelt in small inland lakes are often more darkly coloured than Great Lakes or sea-run smelt. Landlocked smelt may be black on head and back and even the fins may be suffused with black pigment. For a comparison of colour of anadromous and landlocked smelt *see Freshwater Fishes of Insular Newfoundland* (Scott and Crossman 1964, fig. 10, p. 76).

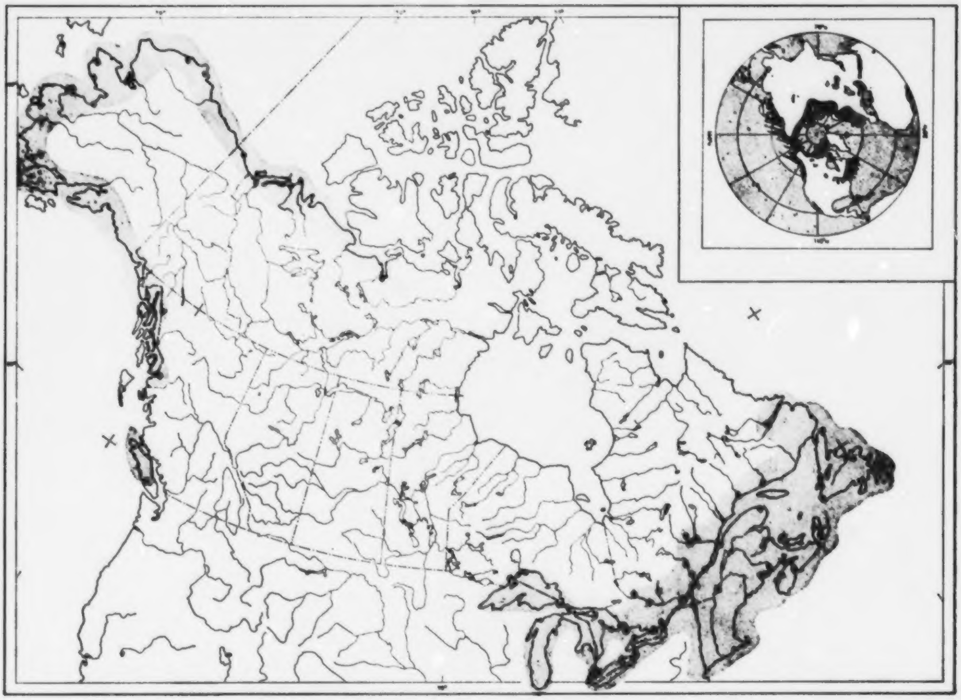
Systematic notes The following outline of the taxonomic history of North American smelts, admittedly brief and overly simplified, is presented with the hope that it will dispel some of the confusion that has arisen in the use of various scientific names for the commercially important eastern North American smelt.

For many years, the smelts of the genus *Osmerus* were considered by most North American ichthyologists to fall into three major taxonomic units — *O. eperlanus* of northwestern Europe; *O. dentex* of the North Pacific and Arctic Ocean waters of both northwestern North America and Asia; and *O. mordax* of northeastern North America. The two forms, *eperlanus* and *dentex*, were considered to be allopatric and, almost since the turn of the century, *dentex* was regarded by some systematists (Berg 1909, for example) as only subspecifically distinct from the type species, *Osmerus eperlanus*, although not all Europeans shared this view.

Gradually, the subspecific designation of *dentex* (i.e. *Osmerus eperlanus dentex*) gained acceptance among North American ichthyologists (Wynne-Edwards 1952; Walters 1955), but not, apparently, as a result of new information, although numerous systematic studies of *O. eperlanus* were written in many European languages. Most North Americans continued to regard the two North American populations as specifically distinct (i.e. *Osmerus dentex* and *O. mordax*) although the tenuous nature of the systematic distinction was soon voiced by Hubbs (1925b).

As early as 1893, Smitt (1893–1895) expressed the opinion that the North American Atlantic smelt was not distinct from the European, a view that was more widely accepted in Europe than in North America. Note, however, that Fortin (1863), in discussing St. Lawrence River fisheries, used *O. eperlanus* when speaking of local smelt.

Finally, a revision of the osmerid fishes was prepared by McAllister (1963), in which the position of the genus *Osmerus* was thoroughly reviewed. McAllister used data from many European studies, plus original data, and concluded that only one wide-ranging species existed: *O. eperlanus*, with two subspecies, *O. e. eperlanus* and *O. e. mordax*. The



subspecies *mordax* was regarded as wide ranging in North America and Eurasia, distinguishable from European *eperlanus* only by the number of pored scales (4–13 in *eperlanus*, 14–28 in *mordax*). McAllister noted, however, that "should sympatric populations of the two forms be found, which did not interbreed, it would be necessary to consider them full species." Such data were presented, albeit in a less than satisfactory form, by Kluikanov (1969) who also noted differences in skull characters and other features. Studies by the present authors indicate a wider range of variation in many characters than observed by Kluikanov and, hence, a weakening of his case. Kluikanov proposed the following nomenclature for smelts of the genus *Osmerus*: *Osmerus mordax mordax* — North American Atlantic smelt; *Osmerus mordax dentex* — North Pacific and Arctic ocean smelt; *Osmerus eperlanus* — European smelt. Thus, we seem to have gone around in a full circle, taxonomically speaking.

Perhaps McPhail and Lindsey (1970) were being realistic by referring to all smelts of the genus *Osmerus*, as the "*Osmerus eperlanus*" complex, and using the one common name "boreal smelt." But, giving all the populations a single name — putting them all in one bag, so to speak —does not make it any easier to talk about them or exchange information about them. Hence, although we are not in full agreement with Kluikanov's reasons, we propose to retain the name *O. mordax mordax* for the American Atlantic smelt, and *O. mordax dentex* for the Pacific and Arctic form, with the common names Atlantic rainbow smelt and Arctic rainbow smelt, respectively.

Distribution The taxonomic position of the species making up the genus *Osmerus* is uncertain at the moment for the reasons noted in the *Systematic notes*, and this nomenclatural uncertainty complicates distributional statements. Therefore, the following information on distribution applies to the so-called Atlantic rainbow smelt and Arctic rainbow smelt that inhabit North American waters.

The original range of the Atlantic rainbow smelt in eastern North America appears to have been restricted to the Atlantic coastal drainage from about New Jersey to Labrador. Reported occurrences south to Virginia are considered doubtful (Bigelow and Schroeder 1963). In addition to the anadromous populations, indigenous landlocked smelt occur widely in inland waters in many parts of eastern North America, such as New Hampshire, Maine, New Brunswick, Nova Scotia, insular Newfoundland (Bigelow and Schroeder's 1963 statement, p. 569, notwithstanding; *see* also Scott and Crossman 1964, p. 76), Labrador, Quebec, and even eastern Ontario (Dymond 1937). The northern limit of range along the North American Atlantic coast is the Hamilton Inlet–Lake Melville estuary, specifically Pike Run Cove, Lake Melville, at 54° 06′ N, 58° 20′ W (Backus 1957). Smelt are landlocked in many Quebec lakes in the St. Lawrence River drainage system, such as St. John, Edward, Memphramagog, Lac des Isles, and Champlain, to name only a few (*see* Delisle and Veilleux 1969, for additional information).

The range of the smelt in the inland waters of North America was extended greatly as a result of introductions into rivers and streams of the Great Lakes watershed. Its establishment in the Great Lakes themselves is generally concluded to have resulted from plantings made in Michigan waters flowing into Lake Michigan. These plantings commenced in 1906 but the planting in Crystal Lake, Mich., in 1912, is considered the one responsible for the eventual establishment of the species in Lake Michigan (Van Oosten 1937b), from whence it spread to all the remaining Great Lakes, except Lake Ontario. It was first reported from Lake Ontario, off Bowmanville, Ont., in 1931 (Mason 1933), 4 years before it was known to occur in Lake Erie; hence, it is unlikely that smelt reached Lake Ontario via Lake Erie, but it is equally unlikely that they occurred there naturally, as suggested by Hubbs and Lagler (1958). It is more plausible that smelt were introduced from waters in New York State via the Cayuga Lake–Cross Lake–Seneca River–Oswego River route.

The spread of smelt through Great Lakes waters has been considered in detail by many authors, notably Creaser (1925), Van Oosten (1937b), and Dymond (1944a). The subsequent spread into inland lakes of Ontario, by unauthorized introductions, has continued to the present day but the impact on native fishes is not known. Smelt are now known to occur in many lakes of the Parry Sound–Muskoka region where sizable spawning runs occur in some lakes, and even in Lake Simcoe where the species was first caught in 1962 (Scott 1963). We were unable to verify the suggestion by MacCrimmon and Skobe (1970) that smelt occur in Cameron and Sturgeon lakes of the Trent Canal System. It now occurs also in Eva Lake, Rainy Lake basin.

The Arctic rainbow smelt, called *Osmerus dentex* in much of the early literature, occurs from Vancouver Island, north to Yakutat on the Pacific Coast. On the Bering Sea side of the Aleutian Islands, it occurs from Bristol Bay, around the Alaskan coast to the Arctic Ocean, thence east along the Canadian coast to Cape Bathurst. This eastern limit is apparently based on a single specimen reported in 1913, which has subsequently disappeared (Walters 1955). It has been more frequently reported in the Mackenzie River delta region than elsewhere in the Canadian Arctic, ranging upriver to about the Arctic Red River (Wynne-Edwards 1952). This same form ranges west into Eurasian waters, being displaced in the region of the White Sea by the European smelt, usually called *O. eperlanus*, which ranges south along the European coastal regions to the British Isles and France.

Biology The smelt is an anadromous species like the alewife, and, in the spring, leaves the sea or large lake and ascends freshwater streams to spawn. Living in the sea and entering fresh water to spawn seems to have been the usual and most successful way of life for smelt, but, like many anadromous fishes, it can live successfully in fresh water throughout its life.

The life history pattern is much the same for both marine and freshwater populations.

Ripe smelt begin to ascend streams in the spring not long after the ice is out, usually in March, April, or May, the precise time depending on locality and weather. McKenzie (1964) classified streams of the Miramichi River system, N.B., as early, middle, or late, depending on when the spawning run occurred, noting that, from year to year, the time of spawning was quite regular for each stream. Early spawners usually left the stream before water temperatures reached 50° F (10° C), late spawners usually left before temperatures reached 59° F (15° C).

In the Great Lakes region, spawning usually occurs in streams but not invariably so. If exceedingly stormy weather prevails during the spawning period, there is good evidence to indicate that smelt may spawn off-shore on gravel shoals. Indeed shore-spawning may be as successful as stream-spawning and of greater importance to the survival of the species than previously realized (Rupp 1965). Streams in the Great Lakes watershed do not seem to be as readily classified as those in New Brunswick but, in general, spawning runs do not occur until the water temperature rises to at least 48° F (8.9° C) in the earliest streams, or to continue after 65° F (18.3° C) in later streams. Spawning may last for up to 3 weeks, but the peak seldom lasts more than a week. Both Bailey (1964) and McKenzie observed that the lengths of fish of both sexes decreased as the spawning season progressed. In all regions, spawning takes place mainly at night, the spawners dropping downstream to the lake by day. Two or more tuberculated males maintain positions against a female in swift water, the eggs are released in clusters and presumably the milt is released simultaneously. Langlois (1935) has given one of the few written accounts of smelt spawning behaviour and he mentioned that he never observed milt being released. The eggs become adhesive shortly after extrusion (McKenzie said 15–20 seconds) and quickly become attached to bottom gravel. The outer coat of the egg adheres to an object. The coating is pulled off the egg by the current except at the one point of attachment, allowing the egg to sway in the water, balloonlike, attached to the substrate by the holdfast or stalk formed from the coat.

The total number of eggs extruded depends upon the size of the female, larger females having more eggs. The following figures on egg number are taken from McKenzie for the Miramichi, from Baldwin (1950) for South Bay, Lake Huron, and from Bailey for Lake Superior.

	Length of female		Egg number
	(inches)	*(mm)*	
Miramichi R.	5.0–8.2	127–209	8500–69,600
South Bay, L. Huron	5.5–7.5	140–190	9650–26,800
L. Superior	8.1	206	30,705

Bailey calculated that, on the average, Lake Superior fish contained 14,673 eggs per ounce of female. The eggs are 0.9–1.0 mm in diameter and hatch in 2–3 weeks depending on temperature. For Miramichi stocks, McKenzie gave hatching times of 29 days at 42.8°–44.6° F (6°–7° C), 25 days at 44.8°–46.4° F (7.1°–8.0° C), and 19 days at 48.2°–50.0° F (9°–10° C). The young are about 5 mm long when hatched, and drift downstream to lake or estuary. Growth is fairly rapid, depending upon the local environment. In a few months the young may measure 20–40 mm long and are exceedingly slender and nearly transparent. By August they may be 2 inches (51 mm) long and can be found close inshore along sand and gravel beaches. The embryology of the smelt was described and illustrated by Kendall (1927) but the figure used is taken from Ehrenbaum (1894) and applies to *O. eperlanus*. *See also* Marcotte and Tremblay (1948).

The age of smelt can be determined by examination of scales. Growth continues to be rapid. For Lake Superior stocks, Bailey noted that none were mature after one growing season, a few after two, and all were mature after three growing seasons. McKenzie noted for Miramichi stocks that 66% of spawners were 2 years old, 30% 3 years old, and the remainder 4, 5, and 6 years old. Lengths for each age group are given in the table below; males and females are listed separately since females grow faster and larger, and live longer than males. The figures apply to fish caught in spring. Sources are McKenzie (1964) for Miramichi River, Baldwin (1950) for Lake Huron, Bailey (1964) for Lake Superior.

The size of fish varies from place to place but smelt landlocked in small inland lakes often attain a maximum size of about 4 inches (102 mm), whereas 14 inch (356 mm) fish have been taken in Lake Ontario and maritime coastal waters.

Smelt are essentially schooling, pelagic fishes, inhabiting midwaters of lakes or inshore coastal waters. They do not inhabit the flowing waters of streams or rivers except at spawning time. They are sensitive to both temperature and light, especially the latter. Ferguson (1965) noted that, in Lake Erie, most smelt were at or near the bottom, at depths of 80 feet or more during daylight hours. *See* Ferguson for a discussion of bathymetric distribution. Preferred temperatures are rather vague but Hart and Ferguson (1966) suggested most of the population in Lake Erie occupied water of about 45° F (7.2° C) although they would enter 60° F (15.6° C) water for brief periods. Many populations exhibit a pronounced postspawning mortality, and windrows of dead smelt may be cast up on shore, as occurs in Lake Erie in May or June. Lake Erie also suffered a severe mortality of young-of-the-year in the fall of 1969.

In some inland lakes in Quebec or the Maritime Provinces, the presence of a few dead smelt on shore may be the only evidence of indigenous populations. The fish are often very small in size, 3–4 inches (76–102 mm) long, and few in number.

Great Lakes smelt populations suffered one of the most catastrophic natural mortalities ever recorded for a North American animal when the huge stocks in Lake Huron and Lake Michigan died off, presumably as a result of some communicable disease, possibly a virus. The mortality commenced in the fall of 1942 in Lake Huron and spread progressively throughout that lake and into Lake Michigan. The total loss from 1942 through to 1946 was estimated at about 50 million pounds (Van Oosten 1947).

Smelt are carnivorous fishes, feeding on a wide variety of smaller creatures, a feature of their life history that has been of intense interest to biologists and fishermen alike. Food studies of freshwater populations have been conducted for many populations but studies in the Great Lakes have shown that *Mysis relicta*, a shrimp-like crustacean, is a primary food. Other invertebrates eaten include amphipods, ostracods, aquatic insect larvae, and aquatic worms. Fish seldom occurs in a high percentage of stomachs but constitutes about 6–10% of the volume. In the Great Lakes, sculpins of the genus *Cottus*, and small smelt, are commonly eaten but, in addition, small burbot, white bass, whitefish, and emerald shiner have also been reported. Young perch, rock bass, and emerald shiners have been found in smelt stomachs from inland Michigan lakes (Creaser 1925, 1927). Despite the fact that studies have not exposed the smelt as

			Age (*years*)					
		Length	1	2	3	4	5	6
Miramichi R.	M	*inches*	–	5.3	6.0	6.7	7.2	–
		mm	–	135	152	169	183	–
	F	*inches*	–	5.5	6.3	7.2	8.1	–
		mm	–	139	160	183	206	–
South Bay, L. Huron		*inches*	–	5.4	6.1	7.2	–	–
		mm	–	117	155	183	–	–
L. Superior	M	*inches*	2.6	6.0	7.3	7.9	8.6	–
		mm	66	152	185	201	218	–
	F	*inches*	2.6	5.9	7.7	8.7	9.4	9.8
		mm	66	150	196	221	239	249

a heavy predator of other fishes, it is still regarded with suspicion by many biologists and fishermen. It is said that lake trout populations decline when smelt enter a lake and indeed this seems generally to be true, although no evidence of direct predation on young trout by smelt has been demonstrated (Kendall 1927; Schneberger 1937). Studies must be conducted throughout the year, however, to be effective and winter is a difficult time to sample, although smelt appear to be more piscivorous during winter months. Also, they occur in such huge numbers (McKenzie estimated 375 million fish in Miramichi stock) that predation by even a very small percentage could be significant.

Smelt, in turn, are preyed upon by a variety of creatures, including their own species, but especially by lake trout. It is a most important prey of landlocked salmon in Maine lakes (Rupp 1968) and undoubtedly in Canadian coastal waters containing landlocked salmon. It is of interest to note that smelt were introduced into Michigan waters in the early 1900's as food for introduced landlocked salmon. In coastal regions large brook trout also feed on smelt. Other species known to feed on smelt include burbot, walleye, and perch, and during the postspawning mortality, a wide variety of birds such as gulls and crows.

The smelt is host to a number of parasites but one species in particular, *Glugea hertwigi* Weissenberg has become obvious in some North American populations. This is a microsporidian parasite that infects smelt in Europe and North America. An acute epidemic of microsporidiosus caused by this parasite occurred in Loon Pond, N.H., in September and October, 1951 (Haley 1952). The parasite is not known to be a human pathogen, but is aesthetically undesirable. The infection appears as white cysts, 0.2–3.5 mm in diameter, attached to the gonads, intestinal tract, or elsewhere in the body cavity. In extreme cases, the cysts may invade the muscle. It has been reported from Lake Erie, and many parts of Quebec, and exhibits seasonal abundance. For further information on the infection of smelt by *Glugea see* Dechtiar (1965), Delisle (1969), and Delisle and Veilleux (1969). The latter authors mapped the distribution of the occurrence of this parasite on smelt in Quebec.

In a study of the parasites of smelt from Lake Huron, Bangham (1955) found that all 50 smelt examined were parasitized, some with acanthocephalans and some with numerous flukes (*Diplostomulum* sp.) in the lenses of the eyes. He did not record *Glugea*.

In a summary of parasites of smelt in North America, Hoffman (1967) listed *Diphyllobothrium osmeri* (from *Osmerus dentex*) and a number of species of trematodes, cestodes, nematodes, acanthocephalans, plus a leech, *Piscicola punctata*, and a crustacean, *Argulus alosae*, and, of course, *Glugea hertwigi*.

Relation to man Marine smelt in Canadian Atlantic coastal waters have supported a commercial fishery for over 100 years. As early as 1852, Perley reported that "The smelt . . . is found in excessive abundance in all the rivers and streams flowing into the Gulf." He also noted that they were often called "frost fish" when angled through the ice, and that after the ice disappears, ". . . they rush in almost solid columns up the brooks and rivulets to spawn and are then taken by cart loads."

The major fishery for smelt in the eastern Canadian provinces is in the Gulf of St. Lawrence region of New Brunswick, especially in the Miramichi River and estuary. The history and conduct of this fishery was fully documented by McKenzie (1964). A few thousand to a few hundred thousand pounds are landed in Nova Scotia, Prince Edward Island, Newfoundland, and Quebec each year. A summary of the catches, in thousands of pounds, by provinces for the years 1964–68 inclusive is shown in the accompanying table.

	1964	1965	1966	1967	1968
Nfld.	29	20	35	51	17
P.E.I.	488	463	631	435	479
N.S.	298	277	338	279	318
N.B.	2584	2978	2630	2148	1920
Que.	742	641	764	761	1036
Ont.	12,886	11,918	16,056	12,661	12,490

A surprisingly successful smelt fishery developed in the late 1950's and early 1960's in the Canadian waters of the Great Lakes, particularly in Lake Erie. The fishery in the Ontario waters of Lake Erie has expanded into a multimillion-pound catch in less than 20 years, from 65,750 pounds in 1950 to 15,913,984 pounds in 1966. These large catches are taken mainly by otter trawls.

The smelt is also a very popular sport fish in many parts of the country. In Newfoundland, Quebec, and parts of the Maritime Provinces, smelt are caught either by winter angling through the ice, or by dipnetting or seining during the spring spawning run, or both. In the Great Lakes region of Ontario, smelting expeditions on spring evenings for spawning smelt have become increasingly popular. Ontario smelt fishermen are permitted to use a 6-foot square dipnet or a seine up to 30 feet long. In 1960, Roseborough (1962) estimated that 68,000 smelt fishermen caught 5.3 million pounds of smelt in Lake Erie alone. To the present, unknown thousands of smelt fishermen try their luck in April and May all through the Great Lakes region. They also fish the many inland lakes where it has been recently introduced, but particularly the Muskoka and Parry Sound regions of Ontario. Smelt is the only fish, other than bait fishes, that can legally be taken from Ontario waters at night by means other than angling.

The smelt was not always considered to be an asset in the Great Lakes. In the 1930's it was heartily condemned as a nuisance by gillnet fishermen because it was caught in their nets in such large numbers and created a serious removal problem. Some gillnets were boiled in large vats to assist in freeing them of smelt. It is ironic that from a position of such low esteem the smelt should rise to first place, by weight, among all Great Lakes fishes in Canadian commercial landings in 1966.

Smelt has been renowned as a food fish for decades and is in high demand. The larger but scarcer Atlantic smelt commands the higher price and is often sold whole or in the round. Great Lakes smelt, which are caught in large numbers by midwater trawls, are usually mechanically processed (headed and gutted) and sold fresh, frozen, and precooked.

Smelts have a most characteristic odour, a smell that is usually likened to the odour of freshly cut cucumbers. The odour, which is particularly strong when large numbers are caught during the spawning runs, is undoubtedly the feature responsible for the common name.

Nomenclature

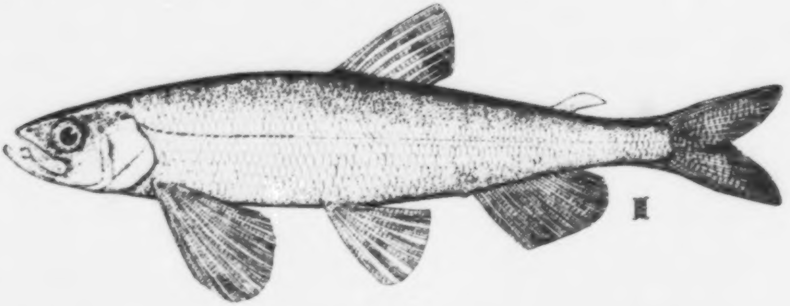
Salmo Eperlanus — Linnaeus 1758: 310 (type locality Europe)
Atherina mordax — Mitchill 1814: 15
Osmerus viridescens — LeSueur 1818a: 230
Salmo (*Osmerus*) *eperlanus* (Artedi) — Richardson 1836: 185
Osmerus eperlanus — Fortin 1863: 120
Osmerus mordax Gill ex Mitch. — Gill 1865: 259
Osmerus sergeanti — Norris 1868: 93
Osmerus dentex — Steindachner 1870: 429
Osmerus spectrum — Cope 1870: 490
Osmerus mordax Mitchill — Cox 1896b: 66
Osmerus mordax (Mitchill) — Jordan and Evermann 1896–1900: 523
Osmerus eperlanus dentex — Wynne-Edwards 1952: 17

Etymology *Osmerus* — *osme* — smell or scent; *mordax* — biting.

Common names Rainbow smelt, smelt, American smelt, leefish, freshwater smelt, frost fish. French common names: *éperlan arc-en-ciel, éperlan du nord.*

LONGFIN SMELT

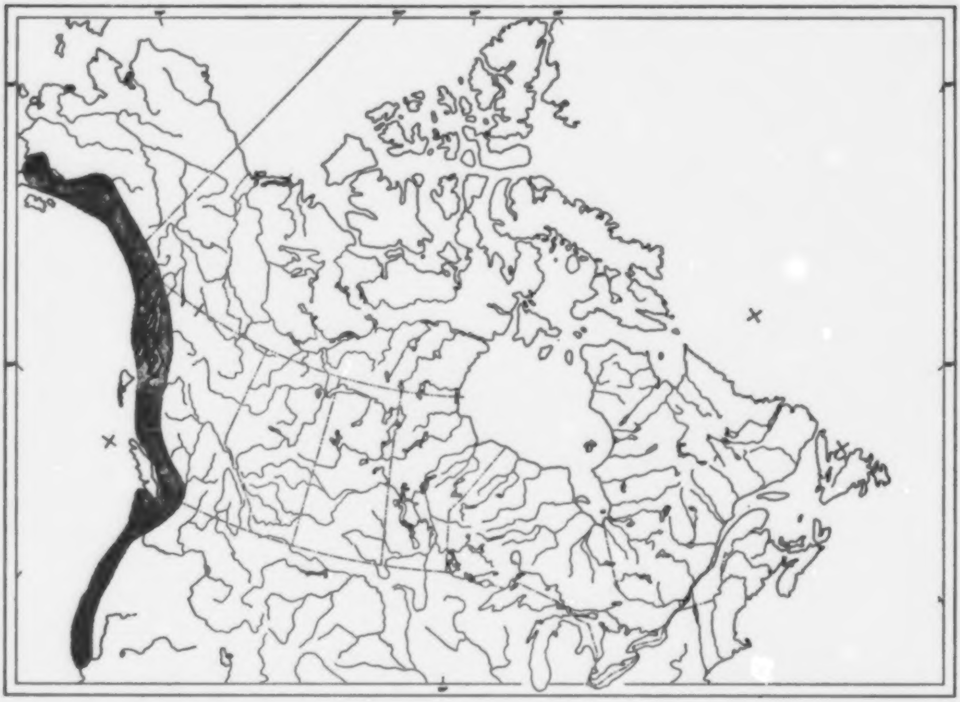
Spirinchus thaleichthys (Ayres)



Description Body elongate, laterally compressed, cross section a long narrow oval, depth 15.1–19.6% of standard length; a small fish rarely over 6 inches (150 mm) in length. Head short 21.7–27.0% of standard length, eye moderately large about equal to snout, 22.2–27.7% of head; mouth large, oblique, maxillary extending short of or to posterior edge of orbit in adults, shorter in young; angle of premaxillaries to forehead 68–90°; snout obtuse, 0–3 horizontal striae on operculum; small teeth on both jaws, tongue, vomer, palatine, mesopterygoid, pharyngeal plates, and basibranchial bones. Gill rakers long and slender, 38–47 (10–13 + 27–34). Branchiostegal rays 7 or 8. Fins: single, soft rayed dorsal at midpoint of body, moderately high, with 8–10 principal rays, tip squarish; adipose rounded, base 1.7 times diameter of orbit; caudal forked, with 19 principal rays; anal with long base, 15–19 principal rays, longest ray 45.4–71.4% of head length; pelvics under dorsal, insertion sometimes anterior to origin of dorsal, long, with 8 rays; pectorals long, about equal to head length, reaching to just short of, or past the pelvic insertion, with 10–12 rays, the common name is based on the long paired fins; first ray of paired fins and rays of dorsal and anal fins enlarged and stiffened in males, upper surface of paired fins tuberculate in ripe males. Scales cycloid, moderately large, 54–63 in lateral series, tuberculate in ripe males; lateral line incomplete, with 14–21 pored scales extending about a head length along body; lateral line region is dilated by a swelling on the underlying muscles in males; pyloric caeca 4–6; gut physostomous, duct attached to anterior end of swim bladder. Vertebrae 55–61. (McPhail and Lindsey 1970; McAllister 1963).

Colour Adults dusky or olive-brown above, silvery below, fins usually stippled along the rays, but interray membranes clear, young (to 2.8 inches or 70 mm) translucent with 2 rows of large black spots, one on each side of the midline of the back, from head to caudal peduncle; peritoneum silver with light speckling. The backs of males at spawning time are moss-green in colour. There is dense black speckling on head and dorsal surface of body, particularly marked in spawning males. The peritoneum is silvery with black speckling.

Systematic notes In 1934 Schultz and Chapman described a new smelt, *S. dilatus*, examining specimens from the Puget Sound, Wash. area, and one from Harrison Lake, B.C., (ROM 6359). They distinguished this new species from Ayres' (1860) more southerly *S. thaleichthys* on the basis of scales, anal rays, and pectoral length. The longfin smelt retained this name until McAllister, as quoted by Dryfoos in 1961 and in the revision of the genus in 1963, showed there was only clinal



variation and synonymized the two forms under the older name.

Distribution Restricted to the west coast of North America from San Francisco, Calif., to Gulf of Alaska (McAllister 1963) or Bristol Bay, Alaska (McPhail and Lindsey 1970). Occurring in fresh water in rivers close to the sea except for apparently nonmigratory populations in Harrison Lake and lower Fraser River valley in British Columbia and Lake Washington near Seattle, Wash.

In Canada it is known in fresh water only from Harrison Lake, the Fraser River below New Westminster, B.C., and the Taku River.

A Harrison Lake specimen, taken in 1921, constitutes the first record of this species in Canada (ROM 6359).

Biology The longfin smelt is an anadromous species. It is so limited in range in Canada that very little is known of its biology here. Spawning in anadromous populations in British Columbia takes place from October to December in freshwater streams close to the ocean (Clemens and Wilby 1961). A landlocked population in Lake Washington spawns from December to mid-February. Females 4.7 inches (120 mm) long lay about 18,000 eggs which are about 1 mm in diameter. Eggs hatch experimentally in 40 days at 44.5° F (6.9° C). The newly hatched larvae are between 7 and 8 mm in length. Young have been observed moving down the spawning streams in April.

In the southern part of their range longfin smelt mature and spawn in their second year regardless of size at that time. Only a few survive this spawning and most of these are females 3 years old.

Hart and McHugh (1944) reported individuals from Burrard Inlet 3.66–5.28 inches (93–134 mm) in standard length. Average length of males (4.17 inches or 106 mm) was only slightly less than that of females (4.33 inches or 110 mm). Scales showed these fish were in their second year of life.

The food of the young in fresh water was said by Hart and McHugh (1944) to consist solely of *Neomysis mercedis*, a shrimp. Other small crustaceans, particularly euphausiids, copepods, and occasional Cumacea, constitute the food of larger individuals in brackish or salt water.

Relation to man Although apparently abundant and readily obtainable on the annual spawning migration up coastal rivers, this species is not utilized commercially or otherwise. The flesh is edible but is soft, oily, and spoils easily.

Nomenclature

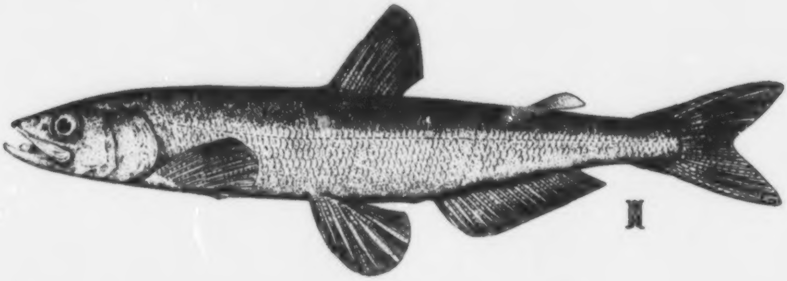
Osmerus thaleichthys — Ayres 1860: 62 (type locality San Francisco)
Spirinchus dilatus — Schultz and Chapman 1934: 67
Spirinchus thaleichthys — Dryfoos 1961: 476

Etymology *Spirinchus* — probably from a Dutch word *spiering* for smelt; *thaleichthys* — rich fish, referring to a high oil content.

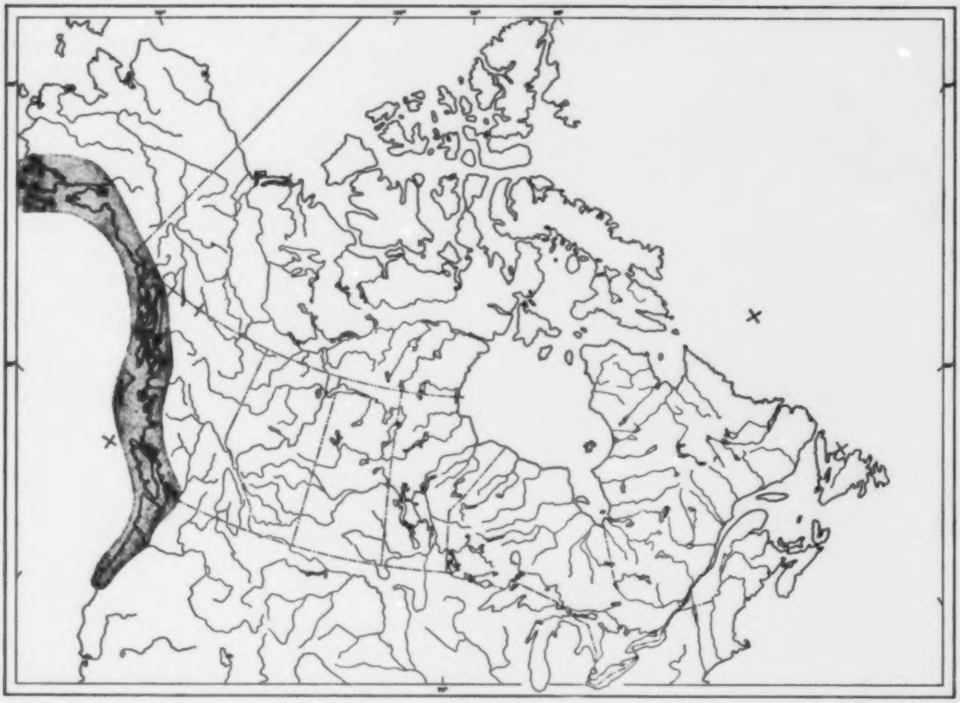
Common names Longfin smelt, long-finned smelt, Sacramento smelt, Pacific smelt. French common name: *éperlan d'hiver*.

EULACHON

Thaleichthys pacificus (Richardson)



Description Body elongate, laterally compressed, cross section an oval; greatest depth, at dorsal fin, 14.7–20.0% of standard length; usually no longer than 8 inches (203 mm); in spawning males there is a distinct raised ridge along the midlateral area of the body. Head short, 20.0–26.3% of standard length, bears tubercles in ripe males; eye small, about 50% of snout length; snout pointed, jaws equal; mouth large, oblique, maxillary extending to or past posterior margin of orbit in adults; small pointed teeth on



both jaws, tongue, palatine, mesopterygoid, pharyngeal plates, and basibranchial bones, 2 canines on the vomer, teeth tend to be lost in spawners. Gill rakers long, about 66% of orbit, and slender, 17–23 (4–6 + 13–18) in number. Branchiostegal rays 6–8; strong concentric striae on operculum and suboperculum. Fins: a single, soft-rayed dorsal at midpoint of back, moderately high, tip lunate, with 10–13 principal rays; adipose rounded, base shorter than diameter of orbit; caudal forked, 19 principal rays; anal with long base, almost equal to head length, with 18–23 rays, edge somewhat lunate; pelvics moderately long, 17.6% of standard length in males, 14.3% in females, often reaching anus in males, much shorter in females, origin anterior to dorsal origin, 8 rays; pectorals only moderately long, 15.8% of standard length in males, 14.3% in females extending 52–74% of the distance to the pelvic insertion, 10–12 rays, tip rounded; all fins with well-developed tubercles in ripe males. Scales cycloid, small, tuberculate in ripe males, 70–86 in lateral series; lateral line complete; 8–12 long pyloric caeca. Vertebrae 65–72. (McPhail and Lindsey 1970; McAllister 1963; Hart and McHugh 1944).

Colour Adults are brown to blue-black on the back and top of the head, the sides are lighter to silvery white, and the ventral surface white; speckling is fine, sparse and restricted to the back. The fins are usually immaculate but the caudal and pectoral fins can be dusky. The peritoneum is light with black speckles.

Distribution The eulachon occurs only on the west coast of North America, from the Klamath River in California to the eastern Bering Sea in Bristol Bay, Alaska, and the Pribilof Islands.

In Canada it is common along the whole coast of British Columbia, particularly in the larger inlets. The eulachon was first recorded from Canada in 1866 by Günther on the basis of specimens collected near Vancouver Island by C. B. Wood, surgeon of HMS *Plumper* and forwarded to the British Museum (Clemens and Wilby 1961).

Biology The eulachon is an anadromous smelt that moves short distances up coastal freshwater streams, often just as the ice is breaking up, in order to spawn. Mixing between the populations using different spawning rivers is not extensive as there are significant differences in meristic characters between various river populations (*see* Hart and McHugh 1944). The spawning migration lasts from mid-March to mid-May, duration of run decreasing south to north. Males predominate early in the run and appear to be more numerous at all times than the females, which arrive later. In the Fraser River the main spawning areas seem to be in 8 miles of river between Chilliwack and Mission, B.C., in 25 feet of water, in areas of coarse sand. They travel a maximum of 15–20 miles up the Nass River. Water temperature at spawning time is 40°–46° F (4.4°–7.8° C). No nest is built, the eggs are scattered and abandoned. Females between 5.7 and 7.3 inches (145–185 mm) in standard length produce 17,000–40,000 eggs, with 25,000 the average number (apparently as high as 60,000 in Columbia River). The eggs are irregular in shape, and preserved eggs vary in size from 8 to 10 mm in diameter. There are numerous oil globules in the yolk (Hart and McHugh 1944). Most adults die after spawning but a few survive, return to the sea, and may return to spawn a second time (Barraclough 1964). The eggs are adhesive and stick to the coarse sand particles. The egg, as it leaves the female, has a double outer membrane. The outer layer breaks, turns inside out but remains attached to the inner membrane at one spot. This forms a short stalk and the free edges of the adhesive outer membrane stick to the sand. Eggs take 2–3 weeks to hatch and the newly hatched young are about 4–5 mm long; they are slender, transparent, and closely resemble young herring. The yolk sac is attached farther back and the vent is more anterior than in herring. The larvae, which are feeble swimmers, are carried downstream and out to sea shortly after hatching. Some seen in salt water in April were 23 mm long. By December they have grown to 1.8–2.0 inches (46–51 mm) in length. The young, carried by currents, become widely distributed in areas like the Strait of Georgia. As they grow, they move into deeper water and are most often caught by trawls fishing in the food-rich echo-scattering layer. Age–length relation in the sea, based on length frequency data given by Barraclough (1964), is as follows:

Age	FL	
	(inches)	*(mm)*
0+	0.7–2.8	18–71
1+	2.8–3.7	71–95
2+	2.8–4.4	72–111
3+	4.1–5.7	104–144
4+	5.1–6.1	129–155
5+	6.5	165

Developing sexual maturity is first noticed in eulachon 2 years old in late summer to winter. They do not spawn for the first time until they are 3 years of age. Barraclough's (1964) figures would put them between 4.1 and 5.7 inches (104–144 mm) fork length at this time. Hart and McHugh (1944) listed standard length of spawning males as 5.5–7.4 inches (140–189 mm) and of spawning females as 5.5–7.7 inches (140–195 mm), but these figures could include older fish spawning for a second time. Apparently some live as long as 5 years but most die after the first spawning in their third year.

Clemens and Wilby (1961) gave length as up to 12 inches (305 mm) but 8 inches (203 mm) would appear to be the average maximum length. It is the largest of the west coast smelts.

Most of the life of the eulachon is spent in the moderate depths of the ocean not far from shore, apparently in the echo-scattering layer. They apparently remain in the depths on their spawning migration until very close to the mouths of the rivers. Those adults that survive the spring spawning migration spend little time in fresh water. The newly hatched young remain in fresh water only as long as it takes them to be passively carried downstream from the spawning grounds to the sea.

Little was known of them in the sea until publication in 1964 of Barraclough's data, obtained from trawls hauled in the echo-scattering layer.

Juvenile and adult eulachon in the sea have been shown to feed primarily on euphausiids, crustaceans, and cumaceans. Feeding ceases when they enter fresh water. The young probably do not feed on their downstream passage to the sea, but live off the yolk.

Eulachons are competitors of other plankton feeding fishes dwelling in the food-rich echo-scattering layer of the sea. As plankton feeders they are not predators on other fishes. They constitute an important food item of a wide assembly of intermediate and terminal predators, especially when they concentrate in vast numbers during the spring migration. They have been reported as making up the principal food at that time of spiny dogfish, *Squalas acanthias*; white sturgeon, *Acipenser transmontanus*; the various Pacific salmons, *Oncorhynchus*; Pacific halibut, *Hippoglossus stenolepis*; Pacific cod, *Gadus macrocephalus*; such marine mammals as harbour seals, sea lions, porpoises, killer whales, finback whales, and a wide variety of sea birds, such as ducks and gulls. Swan (1881) quoted an 1863 account that said the cloud of gulls hovering over the migrating eulachon resembled a heavy fall of snow.

Relation to man Today the eulachon is taken commercially by drift gillnets, principally in the Fraser River. It is utilized as human food and as food for commercially reared fur-bearing mammals. The flesh is oily, rich, and has the usual smelt odour said to resemble the scent of cucumbers or the wild syringa shrub, *Philadephus*. The flavour is good and the eulachon ranks highly among North American food fishes. Eulachon, like other smelts, are usually cleaned and fried whole, sometimes after having been rolled in crumbs. This species was first taken commercially in 1877 in the Nass River for its oil for export, but most of it was sold to local Indians instead. Some was shipped to England in later years, but no export market ever developed. The oil, which has the consistency of soft butter below 70° F (21.1° C), was for some time looked upon as a substitute for cod liver oil as a tonic.

Preparation of salted and smoked eulachons developed later, chiefly on the Nass River. It reached its peak about 1903, short of 2 million pounds, with 4070 barrels salted, 45,200 pounds smoked, and over one million pounds sold as fresh fish at a total value of $96,436 (Hart and McHugh 1944). In 1912 the eulachon was fifth in market value at $78,950 but since that time has declined steadily to minor importance. Most of the catch today goes to fur farms.

Use by white men has always been secondary to that by the native peoples. The eulachon arrived in vast numbers in the early spring when other foods were not yet available and stored foods had been largely used up. The native eulachon fishery was tremendous, extensively governed by ritual, traditional ownership of good sites, rivalry, and an extensive trade network to the interior of British Columbia. The name of the Nass River is supposed to be a Tlingit word meaning food depot. The oil or "grease" (*kleena*) from the eulachon was held in high regard as a food item for cooking and as a curative. The fish were left in piles for several days, then heated in water, and the oil skimmed off the surface. The pulp was later pressed to get the remaining oil. In times of low availability eulachon oil sold for $1.25/gallon. At other times the price was 50¢/gallon. Trails used by Indians to get to the coastal fishing grounds, and over which the oil was carried for trade, were known as "grease trails." Around 1881, 5000 members of the Tsimshian tribe alone moved annually to fishing locations on the coast. Between 1935 and 1940 crude statistics were kept of the Indian fishery, which exceeded the commercial catch in those years by as much as 7000 cwt. Lord (1866) and Swan (1881) both described in interesting detail the pole, basket, and net fishery, some of the ritual associated with pacifying the eulachon so it would come again, and the drying, smoking, and preparation of oil by the Indians. The native fishery still exists and the number taken probably exceeds the commercial catch.

The second common name of this fish, candlefish, was derived from its unique use. The oil content is so high that, after drying, the whole fish can simply be ignited by setting flame to the tail to produce light. Prior to the availability of wax candles and inexpensive oil lamps in the coastal region, light was obtained by forcing a rush or cloth wick down into an eulachon through the mouth. This wick was then lit like that of a candle.

Nomenclature

Salmo (*Mallotus*) *pacificus* — Richardson 1836: 226 (type locality Columbia River)
Thaleichthys stevensi — Girard 1859: 325
Osmerus pacificus — Swan 1881: 258
Osmerus albatrossis — Jordan and Gilbert (1898) *in* Jordan and Evermann 1896–1900: 2823
Thaleichthys pacificus (Richardson) — Jordan and Evermann 1896–1900: 2823
Lestidium (*Bathysudis*) *parri* — Chapman 1939: 522

Etymology *Thaleichthys* — oily fish; *pacificus* — of the Pacific.

Common names Eulachon. There are at least a dozen different attempts at the phonetics of the Chinook spoken name for this species. These range from hooligan to uthlecan to yshuh through the obvious variables of oolichan and ulichan. Candlefish, oilfish, small fish, salvation fish, and fathom fish are others. French common name: *eulakane*.

Suggested Reading – Osmeridae

Bailey, M. M. 1964. Age, growth, maturity, and sex composition of the American smelt, *Osmerus mordax* (Mitchill), of western Lake Superior. Trans. Amer. Fish. Soc. 93: 382–395.

Bigelow, H. B., and W. C. Schroeder. 1963. Family Osmeridae, p. 553–597. *In* Fishes of the western North Atlantic (Acipenseroidei, Lepisostei, Isospondyli). Mem. Sears Mar. Res. 1(3): 630 p.

Dymond, J. R. 1944. Spread of the smelt (*Osmerus mordax*) in the Canadian waters of the Great Lakes. Can. Field-Natur. 58: 12–14.

Ferguson, R. G. 1965. Bathymetric distribution of American smelt *Osmerus mordax* in Lake Erie. Great Lakes Res. Div. Univ. Mich. Publ. 13: 47–60.

Fisk, M. 1913. A review of the fishes of the genus *Osmerus* of the California coast. Proc. U.S. Nat. Mus. 46(2027): 29–297.

Greene, C. W. 1930. The smelts of Lake Champlain, p. 105–129. *In* A biological survey of the Champlain watershed. Suppl. 19th Ann. Rep. N.Y. Conserv. Dep. 1929, Pt. IV.

Hamada, K. 1961. Taxonomic and ecological studies of the genus *Hypomesus* of Japan. Mem. Fac. Fish. Hokkaido Univ. 9(1): 1–55 + 9 pl.

Hart, J. L., and J. L. McHugh. 1944. The smelts (Osmeridae) of British Columbia. Fish. Res. Board Can. Bull. 64: 27 p.

Hoover, E. E. 1936. The spawning activities of fresh water smelt, with special reference to the sex ratio. Copeia 1936: 85–91.

HUBBS, C. L. 1925. A revision of the osmerid fishes of the North Pacific. Proc. Biol. Soc. Wash. 38: 49–56.

KENDALL, W. C. 1927. The smelts. Bull. U.S. Bur. Fish. 42: 217–375.

MACKAY, H. H. 1963. Fishes of Ontario. Ont. Dep. Lands Forests, Toronto, Ont. 300 p.

MARCOTTE, A., et J.-L. TREMBLAY. 1948. Notes sur la biologie de l'eperlan (*Osmerus mordax*, Mitchill) de la province de Quebec. Contrib. Sta. Biol. Saint-Laurent, P.Q. 18: 107 p.

MCALLISTER, D. E. 1963. A revision of the smelt family, Osmeridae. Bull. Nat. Mus. Can. 191: 53 p.

MCKENZIE, R. A. 1964. Smelt life history and fishery in the Miramichi River, New Brunswick. Fish. Res. Board Can. Bull. 144: 77 p.

RUPP, R. S. 1965. Shore-spawning and survival of eggs of the American smelt. Trans. Amer. Fish. Soc. 94: 160–168.

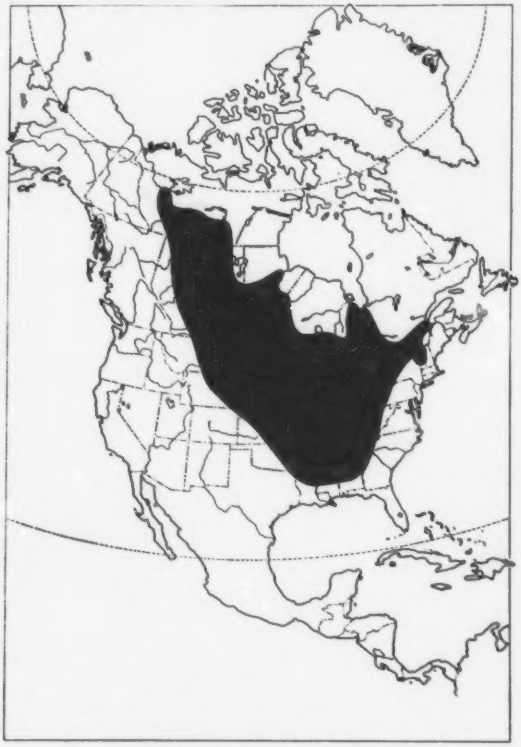
VAN OOSTEN, J. 1937. The dispersal of smelt, *Osmerus mordax* (Mitchill), in the Great Lakes region. Trans. Amer. Fish. Soc. 66: 160–161.

1947. Mortality of smelt, *Osmerus mordax* (Mitchill), in lakes Huron and Michigan during the fall and winter of 1942–1943. Trans. Amer. Fish. Soc. 74: 310–337.

MOONEYE FAMILY — Hiodontidae

Moderate-sized, deep-bodied, laterally compressed, silvery to golden fishes, resembling herrings. The head is naked; the snout rounded; the eyes large and far forward. The lower jaws, maxillary, premaxillary, palatines, parasphenoid, and tongue are all armed with strong teeth. The dorsal fin is situated over the anal fin, distinctly behind the pelvic fins; the anal always has a longer base; the caudal is forked; there is no adipose fin. The body is covered with large, silvery, cycloid scales. The lateral line is present but indistinct. The pectoral girdle has a prominent, expanded coracoid. The swim bladder is connected to the skull.

The family consists of a single genus, *Hiodon*, with two living species restricted to the fresh waters of northern North America. Mooneyes are usually placed with the notopterids in the suborder Notopteroidei and ranked among the early clupeiform fishes.



World Distribution of the Mooneyes

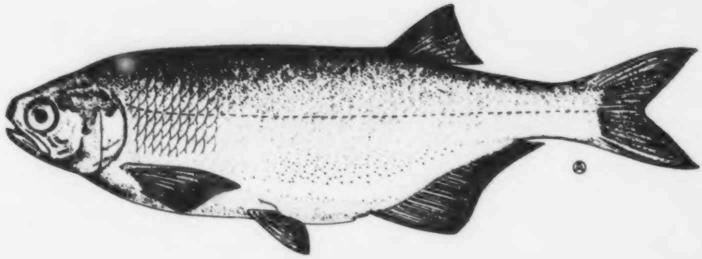
KEY TO SPECIES

1 Ventral surface keeled from isthmus to anal fin; origin of dorsal fin opposite or behind origin of anal fin; maxillary extends beyond middle of pupil .... GOLDEYE, *Hiodon alosoides* (p. 327)

Ventral surface keeled from pelvic fins to anal fin; origin of dorsal fin well ahead of origin of anal fin, maxillary short of, or just to, middle of pupil .... MOONEYE, *Hiodon tergisus* (p. 333)

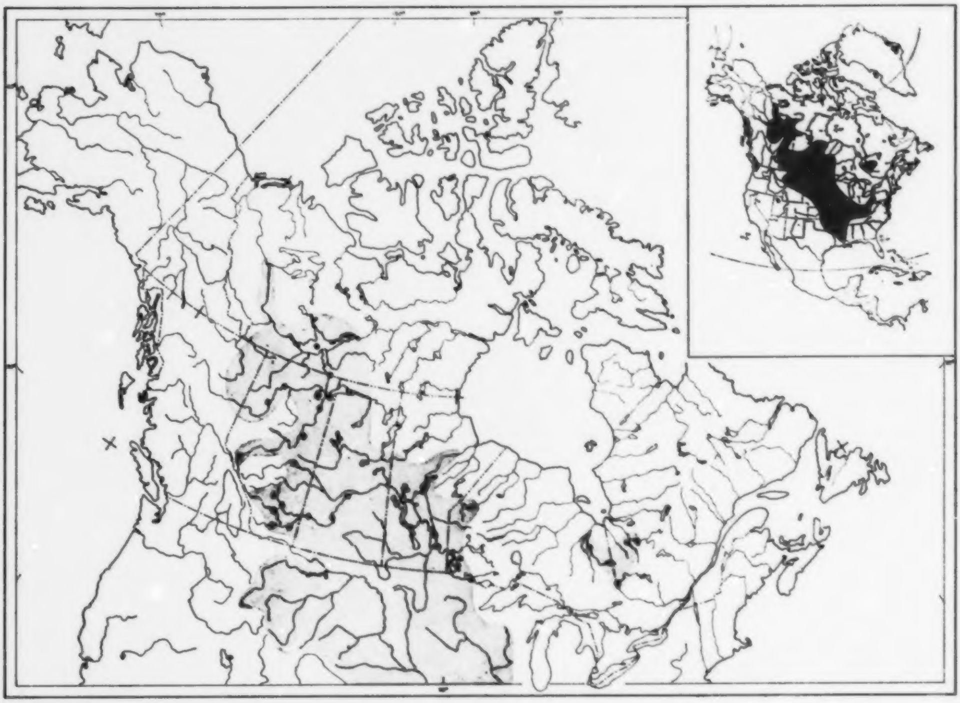
GOLDEYE

Hiodon alosoides (Rafinesque)



Description Body very deep, greatest depth at origin of anal fin 30.2–36.0% of standard length, strongly compressed, greatest width 8.4–12.0% of standard length; ventral edge forming keel (but not serrate) from behind pectoral fins to anus; caudal peduncle moderately short and deep, length (to end of vertebrae) 8.5–12.0% of standard length, least depth 8.7–10.6% of standard length; usually 12–15 inches (305–381 mm) long. Head naked, short, 20.0–23.4% of standard length, narrow, interorbital width 5.4–6.5% of standard length, moderately deep, 15.8–18.7% of standard length; eye far forward, high, and large, 5.2–7.1% of standard length, iris large and a bright golden colour, hence name, supposedly reflect light like those of a cat; snout very short, 3.8–4.5% of standard length, very bluntly rounded, noticeably upturned; mouth large, somewhat oblique, maxillary long, reaching past middle of orbit, 9.6–12.4% of standard length, lower jaw equal to or slightly in advance of snout; teeth rather small, sharp, stronger in males, a large series of canines on each side of parasphenoids, 1 or 2 smaller series between, 2 posteriorly, vomer toothless, palatines with series of canines, pterygoids with bands of villiform teeth, premaxillary with single row of small teeth, maxillaries with minute series at front, dentaries with 3 parallel series of small teeth. Gill rakers 15–17 (6–7 + 9–10), short and thick. Branchiostegal rays 8–10. Fins: a single, short, rather low, soft-rayed dorsal beyond midpoint of body, well behind origin of anal, base 8.0–10.1% of standard length, height 11.0–15.1% of standard length, 9 or 10 principal rays, border slightly concave; caudal deeply forked, tips pointed, moderately broad; anal long and falciform, base covered by 1–3 rows of small scales, its border in mature males notched with greatly expanded, rounded anterior lobe, concave in females, length of base 24.6–30.0% of standard length, greatest height in males 15.3–17.5% and in females 13.4–16.1% of standard length, 29–34 principal rays, posterior rays very short; pelvics short, squarish, length 12.8–15.0% of standard length, 7 rays; long, narrow pelvic axillary process, its length almost 50% of length of fin; pectorals broad, long, pointed, length 19.2–22.4% of standard length, 11 or 12 rays. Scales cycloid, large, 57–62 in lateral series; lateral line complete, almost straight. A single pyloric caecum. Vertebrae 56–61. (Largely from Kerswill 1937.)

Colour In life, goldeyes have a typical herring colour, dark blue to blue-green on the back and upper sides, sides and ventral surface silver, shading to white. The scales are said to have a golden lustre forward and blue to pink near the tail. The eyes are prominent, and the large pupils are bright



yellow. The scales of preserved specimens are golden in colour and the back is brown. The popular commercially brined and smoked goldeye, familiar to many people, is bright red through orange to golden (*see* frontispiece in Kennedy and Sprules 1967). This colour, once achieved by preparing them with the smoke of willow wood only, is now largely produced by harmless aniline dyes.

Systematic notes Measurements of head length, head depth, eye, snout, interorbital width, and maxillary differ in populations from lakes Winnipeg, Abitibi, Athabasca, and Lesser Slave Lake. Kerswill (1937) attributed this to phenotypic variability only. There are significant sexually dimorphic characters as well. A small sample from the isolated eastern population showed no major meristic differences from goldeye in Manitoba.

Distribution The goldeye occurs only in North America. In the northeast there is an isolated pocket of distribution in Quebec and Ontario immediately south of James Bay. The main area of distribution stretches northwest from western Ontario to the Mackenzie River as far down as Fort Norman[1]. In the east it extends southwest below the Great Lakes, through the Ohio and Mississippi River drainages, through Ohio, Pennsylvania, Indiana, Kentucky, Alabama, and Mississippi. In the west it occurs southeast from western Alberta, through eastern Montana and Wyoming, to Oklahoma.

In Canada the isolated area, thought to result from an early connection above the Great Lakes of glacial lakes Agassiz and Barlow–Ojibway, consists of the waters between Lake Waswanipi, Que., Lake Temiskaming (Ottawa River), and Lake Abitibi, including the Nottaway River, flowing into James Bay. The main area starts in Ontario at Rainy Lake, runs north to Sandy Lake, then through the major lakes of Manitoba, down the Nelson

River as far as Limestone Rapids, in the Churchill River in western Manitoba, north in Saskatchewan to the North Saskatchewan River, west in Alberta in the Bow and Red Deer rivers as far as Jasper, north in the North Saskatchewan, Lesser Slave, Athabasca, and Peace drainages, Lake Athabasca, and Great Slave Lake, down the Mackenzie to Fort Norman[1] at the confluence of the Great Bear River and down the Liard River to northeastern British Columbia (Kennedy and Sprules 1967).

Biology In contrast to so many Canadian fishes, it is encouraging to note that the biology of this species in Canada is well documented. Much of the following is derived from the studies or summaries published by Battle and Sprules (1960), Kennedy and Sprules (1967), and McPhail and Lindsey (1970).

Spawning occurs in the spring from May to the first week in July, starting just after the ice breaks up and continuing over a period of 3–6 weeks. During this period temperature is 50°–55°F (10.0°–12.8°C). It takes place in pools in turbid rivers or in backwater lakes and ponds of these rivers. The spawning act has never been seen because of the turbidity of spawning sites, but it is assumed to take place at night. The small amount of sperm produced by the males suggests close approximation of single pairs during spawning. Females from 12 to 15 inches (305–381 mm) fork length contain 5761–25,238 eggs, which are approximately 4 mm in diameter after fertilization. Eggs contain a single, large oil globule, are steel-blue in colour when near maturity, translucent when shed and, unique among North American freshwater fishes, are semibuoyant. They hatch in about 2 weeks. Newly hatched larvae are just over 7 mm long and at first float vertically at the water surface. Growth is slow until July, but by September young goldeye in the Saskatchewan River are approximately 4 inches (102 mm) in length and 11 grams in weight. Growth is slower after September, slower in subsequent years, growth rate decreases from south to north, and, in older individuals, is greater in females than in males in some habitats. Maximum length in July of the first year is as low as 1.1 inches (28 mm) in Lake Abitibi and as high as 2.7 inches (69 mm) in Baptizing Creek, Man. Ages are readily determined from scales, and, based on data from Kennedy and Sprules (1967), the table on p. 330 shows the average age, fork length, and weight relation for males and females from different areas.

Age at sexual maturity varies with sex and increases from south to north. In Lake Claire, Alta., it is 6–9 years for males and 7–10 years for females, and the differential for Manitoba is 2–3 years less. Some males mature at age 1 in South Dakota. It is now assumed female and male goldeye spawn annually after maturity is reached. At the same age goldeye in the Bow River, southern Alberta, weigh almost twice as much as those in Lake Claire, northern Alberta. The largest goldeye recorded by Kennedy and Sprules (1967) was a female from Lake Claire, Alta., that was 17.2 inches (437 mm) in fork length, 2 pounds, 2 ounces in weight and 14 years of age. Trautman (1957) cited a maximum size of 20 inches (508 mm) and a weight of 3 pounds, 2 ounces in Ohio.

Goldeye habitat is most frequently quiet, turbid water of large rivers, the small lakes, ponds, and marshes connected to them, and the muddy shallows of larger lakes. They overwinter in deeper areas of lakes and rivers and move toward the shallow, firm-bottomed spawning sites as the ice is breaking up in the spring. Movement into the Saskatchewan River near Edmonton does not occur until the water is 50°–54° F (10.0°–12.2° C). The underyearling and old fish may utilize separate habitats. In the North Saskatchewan River there is a yearly upstream migration in the spring; after spawning the adult fish continue upstream apparently to feed. There is downstream migration in the fall (Paterson 1966). They are probably inactive in winter as growth, in Canada, ceases during that period. Goldeye are apparently mainly nocturnal and the eyes, which have rods only, no cones, and reflect light, are

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[1] Since this was written goldeye have been taken as far down river as Aklavik.

			Age (*years*)														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
L. Winnipegosis, Man.	F	FL	–	7.2	8.7	10.8	–	12.4	13.6	12.8	–	–	–	–	–	–	–
		Wt	–	3.0	4.3	9.3	–	14.5	15.7	16.5	–	–	–	–	–	–	–
	M	FL	–	6.2	8.6	10.4	11.7	11.9	12.0	12.4	–	–	–	–	–	–	–
		Wt	–	1.5	4.2	8.4	11.8	11.9	12.1	12.5	–	–	–	–	–	–	–
Saskatchewan Delta, Man.	F	FL	6.2	8.4	10.1	11.3	12.0	12.8	13.4	13.8	14.2	15.5	14.5	17.0	–	–	–
		Wt	1.4	3.4	7.0	10.1	13.1	15.8	17.3	18.7	20.0	33.0	20.0	34.0	–	–	–
	M	FL	6.5	8.3	9.9	11.1	11.7	12.3	12.9	13.4	13.9	14.5	–	–	–	–	–
		Wt	1.6	3.2	6.0	8.9	11.6	12.6	14.1	15.5	16.0	21.0	–	–	–	–	–
L. Claire, Alta.	F	FL	–	5.2	7.0	8.3	10.0	10.4	12.0	13.2	13.7	14.8	15.2	15.3	16.0	17.2	–
		Wt	–	0.9	2.0	3.5	4.8	7.5	11.8	15.0	18.0	20.9	24.0	25.8	27.4	34.0	–
	M	FL	–	5.4	7.0	8.2	9.2	10.3	12.1	13.1	13.8	14.3	14.5	14.5	14.2	–	–
		Wt	–	0.9	2.1	3.0	5.7	7.7	11.9	15.1	17.4	19.2	20.0	20.1	18.0	–	–
Sandy L., Ont.	F	FL	–	–	–	–	–	10.4	11.4	11.0	11.9	12.2	12.0	–	–	13.2	14.5
		Wt	–	–	–	–	–	7.6	9.9	9.0	12.0	11.8	11.6	–	–	18.0	25.0
	M	FL	–	–	–	–	9.5	10.2	11.2	11.2	11.5	11.7	11.8	11.9	12.2	12.0	–
		Wt	–	–	–	–	5.0	7.0	9.0	10.0	10.5	11.1	11.3	12.7	13.3	13.0	–

According to Kennedy and Sprules (1967), weight–length relation for the various areas is $Y = 3.20X - 2.37$ where $Y = \log_{10}$ of weight (oz) and $X = \log_{10}$ of fork length (inches).

adapted to dim light conditions and to their turbid habitat.

The food of goldeye was extensively analyzed by Kennedy and Sprules and expressed qualitatively, quantitatively, by size, date, and area. The following generalization is derived from their data. The food is of a great variety, consisting of almost any organism encountered. Whatever is most available predominates and there is no indication of any strong food preference. During summer a large part of the food is taken at the surface. Food items range from surface insects (corixids dominate) to aquatic insects (mature and immature), other insects, other invertebrates including crustaceans and molluscs, limited numbers of small fishes, and other vertebrates (green frogs, shrew, and mice). Corixids, other aquatic insects and other insects make up the bulk of the food. Fishes eaten by goldeye were as follows: northern pike, trout-perch, spottail shiner, yellow perch, log perch, other darters, and ninespine and brook sticklebacks. Each of 9 fish examined at Sandy Lake, Ont., in September of 1953, contained a single mouse only. Food of young-of-the-year goldeye is mainly microcrustaceans (*Daphnia*, *Diaphanosoma*, *Acroperus*, *Bosmina*, *Moina*, *Diaptomus*, and *Cyclops*) with minor amounts of insects and other invertebrates.

Principal predators of goldeye in order of importance are northern pike, walleye, sauger, and inconnu. Cormorants, *Phalocrocorax auritus*, eat many goldeye, and it is assumed several other birds and mammals are minor predators.

Since goldeye feed so extensively at the surface in summer, they would appear to compete with few other fishes for food but probably do compete for space. Their apparent selection of, and adaptation to, turbid waters possibly limits their competition with other fishes, most of which are less so adapted.

Parasites listed by Kennedy and Sprules included Cestoda (3), Trematoda (3), Nematoda (1), and Crustacea (1). Hoffman (1967) listed only 2 trematodes and 2 cestodes. Self (1954) stated that goldeye in Lake Texoma harboured large numbers of cestodes but mentioned no serious effect of them.

Relation to man Commercial landings of goldeye in Canada were reported as early as 1876. Until the early 1900's these fish were taken haphazardly in gillnet catches of lake whitefish, walleye, and northern pike.

Goldeyes have never been very acceptable as fresh fish and their early use was as dog food for which they earned about 1¢/pound. Taste of fresh goldeye was said to be insipid, muddy, and like that of salted brown paper; the flesh is soft and an unattractive grey colour. As early as 1890 its improved eating quality when smoked was noted. After 1911 the market for the smoked product increased rapidly; fishermen began fishing for them directly, and by 1926–29 annual catches of one million pounds were achieved. From 1931 to 1965 the catch declined and the 5-year average never again exceeded 454,000 pounds (1936–40) and was as low as 180,000 pounds in 1965. Production was once predominantly from Lake Winnipeg (hence name) but catches declined so badly that 1938 was the last year substantial quantities were taken there. Most of the present Canadian production comes from the Saskatchewan River in Manitoba and Saskatchewan, to a lesser extent from an Indian fishery in Sandy Lake, Ont., from Alberta and from Quebec.

Its appearance on the menus of transcontinental trains did much to popularize smoked or Winnipeg goldeye, and it quickly became a gourmet item in price and was promoted as a Canadian delicacy. Since 1930, demand has regularly exceeded the supply. This is one of the few commercial fishes taken in Canada that is almost exclusively prepared and consumed in Canada. Goldeye were even imported to Canada from the United States for processing and sale here. The present yield is almost totally consumed in the region around Winnipeg where they are processed. The 1965 catch in Ontario of 6897 pounds had a marketed value to the fishermen of $1846.00 or about 27¢/pound. The whole, processed fish has sold for as much as $1.30/pound wholesale, and a retail price of approximately $2.00/pound. The retail price in Winnipeg in 1930 was 27¢/pound, and in 1970 $1.49/pound.

Originally the smoking, over willow fires, was carried out at the fishing ports. Willow smoke apparently imparted both the colour and flavour, but the colour faded with storage. With increased commercial production and decreased availability of willow, oak fires were used and the colour added by means of tasteless aniline dyes, which colour the skin but not the flesh. The fish are frozen fresh, then, as needed, thawed, brined, dyed, and smoked for 5–7 hours. After processing they are kept cool but not frozen and must be consumed within a few days. Kennedy and Sprules wrote that "A 'Winnipeg goldeye' represents the triumph of art over nature. Its characteristic color results from an aniline dye. Its characteristic taste is essentially that of oakwood smoke. Its texture has been improved by freezing. Its name is derived from a lake where it is no longer caught in appreciable quantities." Its popularity has led to attempts to substitute mooneye and even tulibee (cisco). There is an excellent colour photograph of a whole, processed Winnipeg goldeye in Kennedy and Sprules (1967).

Goldeye constitute a sport fish in the Mississippi valley and in the Saskatchewan River and its tributaries. It will take wet or dry flies and small spinners. The usual angling method in Canada is a hook baited with insects or a small fish, and held by a float about one foot below the surface. On light tackle they are said to provide good sport.

Nomenclature

Amphiodon alveoides — Rafinesque 1819: 421 (type locality Falls of the Ohio)
Hiodon Clodalis — Richardson 1823: 716
Hiodon chrysopsis — Richardson 1836: 232
Hyodon alosoides — Jordan and Gilbert 1883a: 259
Hyodon chrysopsis Richardson — Jordan and Evermann 1896–1900: 413
Hiodon alosoides — Nash 1908: 51
Elattonistius chrysopsis (Richardson) — Jordan and Thompson 1910b: 353
Amphiodon alosoides Rafinesque — Hubbs 1926: 9
Cyprinus (*Abramis?*) *smithii* Richardson — Jordan, Evermann, and Clark 1930: 41

Rafinesque's *alveoides* is almost always cited as a misprint and given as "*alosoides* (misprinted *alveoides*)." There seems little reason for this decision of later authors. Under genus *Amphiodon* — Rafinesque said fin placement was similar to clupeids and cited the common name yellow herring. In describing *A. alveoides* he said the common name on the Ohio River was Shad but does not use the term shadlike in the description.

The generic name was so regularly changed by later authors on the pretext of "corrected orthography" that many authors, including Kennedy and Sprules (1967), cited Richardson's 1836 description as *Hyodon crysopsis*, misquoting the trivial name as well.

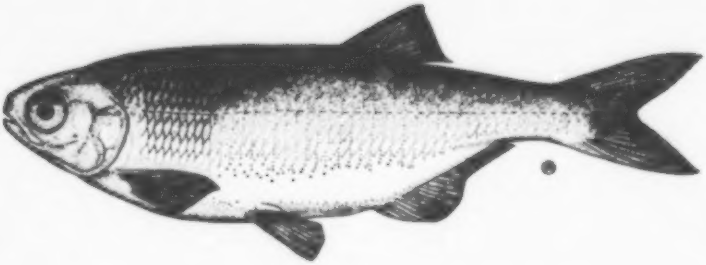
A species described by Richardson (1836: 110) as *Cyprinus* (*Abramis*?) *smithii* (Nob.) La Quesche, from the Richelieu River at the St. Lawrence River is a composite, probably of the mooneye *H. tergisus* and the golden shiner *Notemigonus crysoleucas* (3 branchiostegal rays, 60 lateral line scales, toothed tongue). This name was wrongly referred to *H. alosoides* by Jordan, Evermann, and Clark (1930). The goldeye has never occurred at that location but the mooneye and the golden shiner do. *Cyprinus smithii* was placed in the synonymy of *H. tergisus* by Jordan and Evermann in 1896–1900.

Etymology *Hiodon* — toothed hyoid; *alosoides* — shadlike, referring to its general shape and similarity to shad (*Alosa*, Clupeidae).

Common names Goldeye, Winnipeg goldeye, western goldeye, yellow herring, toothed herring, shad mooneye, la Queche, weepicheesis (Anglicized Indian name). French common name: *laquaiche aux yeux d'or*.

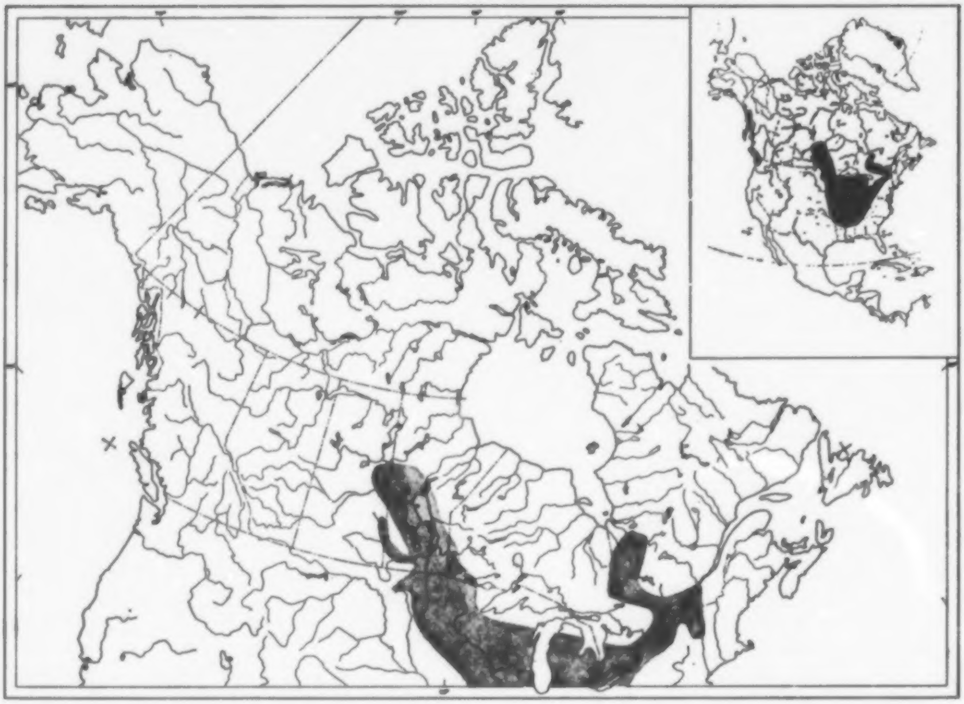
MOONEYE

Hiodon tergisus Lesueur



Description Body very deep, greatest depth at origin of dorsal fin 29.6–36.6% of standard length, laterally compressed but less so than goldeye, body width 11.3–14.5% of standard length; ventral edge keeled (but not serrate) only from pelvic fins to anus; caudal peduncle (to end of vertebrae) moderately long, 11.5–13.4% of standard length, depth less than length, 9.8–11.0% of standard length; fish usually 10–12 inches (254–305 mm) in length. Head naked, short, compressed, and conical, length 20.8–23.9% of standard length, depth 16.5–18.3% of standard length, interorbital width 5.5–6.3% of standard length, less concave over eyes than goldeye; eye far forward, high, and large, 6.6–7.2% of standard length, iris large, golden but not so bright as goldeye, reflects light; snout very short, 4.4–5.2% of standard length, less noticeably upturned and less blunt than in goldeye; mouth smaller, oblique but less oblique than goldeye, maxillary falls short of middle of orbit, 8.8–10.0% of standard length; teeth, smaller and more delicate than goldeye, consisting of a large series of canines on each side of parasphenoids, 1 or 2 small series between them, vomer toothless, palatines with series of canines, pterygoids with bands of villiform teeth, premaxillaries with single row of small teeth, maxillaries with minute series at front, dentaries with 3 parallel series of small teeth. Gill rakers short and thick, 15–17 (6–7 + 9–10). Branchiostegal rays 7–9, usually 8. Fins: a single, short, rather low, soft-rayed dorsal behind midpoint of body, origin in front of origin of anal fin, base 9.8–13.8% of standard length, height 13.0–14.7% of standard length, 10–14, but usually 12 principal rays; caudal moderately long, deeply forked, tips pointed; anal long, base 21.6–25.6% of standard length, falciform, base usually covered by 2 or 3 rows of small scales, origin at midpoint of dorsal fin, in mature males its lower border notched and anterior expanded in rounded lobe, greatest height in females and young 11.4–13.2% of standard length, greater at lobe in mature males, 26–29 principal rays, posterior rays very short; pelvics short, square, length 13.4–17.0% of standard length, usually 7 rays; pelvic axillary scale large, prominent, approximately 50% of pelvic length; pectorals narrower and shorter than goldeye, length 16.0–19.1% of standard length, 13–15 rays. Scales cycloid, large, thin, flexible, 52–57 in lateral series; lateral line complete, almost straight. A single pyloric caecum. Vertebrae 53–57. (Largely from Kerswill 1937.)

Colour Pale olive to brown above with faint steel-blue lustre, sides more silvery than goldeye, silver to whitish below, fins clear to dusky. Eyes golden but usually not so bright as in goldeye. Preserved specimens silvery, not so golden as preserved goldeye.



Distribution Restricted to North America. It extends from James Bay, Ottawa River to the Lake Champlain and St. Lawrence watershed, southwest of the Appalachian Mountains through western New York and Pennsylvania to Arkansas and Oklahoma, northward through the eastern half of the states from Kansas to North Dakota to southeastern Saskatchewan and southern Manitoba. True distribution in doubt because older records often untrustworthy as a result of misapplication of common name.

In Canada, the mooneye has a horseshoe-shaped distribution around the Upper Great Lakes. Starting with the Nottaway River in Quebec, the eastern arm includes the Ottawa, St. Lawrence, and Richelieu rivers, and Lake Champlain in Quebec, the lower Great Lakes excluding Georgian Bay, the North Channel, and Lake Superior. Rare in lakes Huron and Michigan. The western arm includes Lake of the Woods, the southern half of Manitoba and southeastern Saskatchewan as far north as the North Saskatchewan River, west to Cumberland House, Sask., and almost to the headwaters of the Assiniboine River.

Van Oosten (1961) gave records for lakes Huron and Michigan correcting records of Radforth (1944) which he surmised were based on the erroneous application, in the literature and catch statistics, of the name mooneye to several other Great Lakes fishes, especially gizzard shad. Records of its occurrence in the Moose River of Ontario were based on a single ROM specimen for which the locality data is now known to be in doubt.

There is evidence that both the range and density of this species in the United States is shrinking as a result of increased silting. It is apparently not highly adapted to turbid water as is the goldeye. It is much less abundant now in Lake Erie and the Ohio River than in the early 1900's.

Biology This species, unlike the goldeye, has never been of commercial importance and, as a result, very little is known of its biology in Canada. One of few sources of Canadian information may be a study of Lake St. Clair mooneye by Johnson (1951).

Spawning is in the spring (April–May), but possibly in early June in Lake Erie. In areas to the south, mooneye migrate in large numbers up large, clear streams. Females carry 10,000–20,000 eggs. By October young-of-the-year mooneye have reached 4.5–6.5 inches (114–165 mm) in length. (For details and drawings of early development of young *see* Fish 1932). Growth has been interpreted from the scales, and Van Oosten (1961) gave the following age–length and weight relations for Lake Erie mooneye:

Age	Mean calculated TL		Mean wt
	(inches)	*(mm)*	*(oz)*
1	8.4	213	2.9
2	9.6	244	4.3
3	11.6	295	8.1
4	12.2	310	10.3
5	12.6	320	11.2
6	–	–	–
7	13.1	333	12.8
8	14.9	378	14.8

Sexual maturity is reached by at least two-thirds of the males at 3 years of age, earlier than females, which often do not mature before 5 years of age. Males die earlier than females and, in later years, the sex ratio is biased toward females. Different ages dominate in different lakes and there are successful and unsuccessful year-classes.

Maximum age in Lake St. Clair, would appear to be 8 years. Trautman (1957) indicated that maximum known size was 17.5 inches (445 mm) long and 2 pounds 7 ounces in weight.

Trautman said (1957) that south of the Great Lakes, mooneye were abundant only in the clearest, largest waters of Ohio. Although often found in nonflowing waters, it feeds mostly in swift waters. It is less tolerant of silted habitats than the goldeye. Its abundance in Ohio rivers has decreased steadily since 1935 and is very low compared to the numbers known in 1850. This is probably a result of increased turbidity. It migrates up rivers in spring to spawn, lives in shallow water and is rarely taken in gear set below 35 feet (10.7 m).

Johnson (1951) said that mooneye in Lake St. Clair had been feeding on aquatic and terrestrial invertebrates, mainly insects. Trautman (1957) described their habitat as being where there is an abundant supply of small fishes on which they feed. Scott (1967) listed insects, molluscs, crayfish, small fishes, and plankton.

They would be competitors for food only of other surface insect feeders, but they compete with many other species for space and spawning sites. The young are probably forage for several predatory species with which they occur. They have not, however, been often reported as part of the food of such fishes.

Hoffman (1967) summarized the parasites, listing trematodes (7), cestodes (1), nematodes (3), and acanthocephalans (1).

Relation to man Any discussion of this topic is clouded by two problems. The flesh of the mooneye, said by many to be dry, tasteless, and too filled with small bones, has precluded its becoming an important food fish. Several Great Lakes fishes, including gizzard shad, alewife, and various ciscoes, have been called mooneye and so entered in annual statistical summaries of commercial catches. Van Oosten (1961) made an effort to sort out some of these errors. There is no entry in recent Ontario commercial catch summaries for mooneye, but they have been taken commercially by United States fishermen on Lake Erie. Langlois (1954) said that they were smoked and marketed as smoked shiners. In times of shortages of goldeye, the mooneye is often smoked and sold as the more valuable species.

It is nowhere an important sport fish but, like the goldeye, will take a variety of artificial flies and lures and will provide good fun on light tackle.

Nomenclature

Hiodon tergisus — LeSueur 1818a: 366 (type locality Lake Erie at Buffalo and Ohio R. at Pittsburg)
Hyodon tergisus — Günther 1868: 375
Hiodon chrysopsis Richards. — Günther 1868: 376
Cyprinus (Abramis?) smithii Richards. — Günther 1868: 376
Hiodon clodalis of Richardson 1823 — Evermann and Goldsborough 1907a: 98

In 1823, Richardson used Lesueur's name *Hiodon clodalis* (= *Hiodon tergisus*) for a fish caught at Cumberland House, Sask. He said the fish was called "*goldeye.*" In 1836 he referred this specimen to his new species *H. chrysopsis* (= *H. alosoides*). Cumberland House is within the distribution of both the mooneye and the goldeye but it seems obvious that Richardson's fish was a goldeye. Richardson's (1836) species *Cyprinus smithii* has been referred by various authors to both *H. alosoides* and *H. tergisus*. It would appear that this species is a composite of *Notemigonus crysoleucas* and *Hiodon tergisus*.

Hiodon selenops Jordan and Bean, the southern mooneye, long considered a separate species, is now looked upon as conspecific with *H. tergisus*.

Etymology *Hiodon* — toothed hyoid; *tergisus* — polished, probably alluding to its silvery colouring.

Common names Mooneye, moon-eye, toothed herring, toothed herring of the lakes, river whitefish, notch-finned Hiodon, fresh-water herring. French common name: *laquaiche argentée*. The common name mooneye was apparently often mistakenly applied to goldeye, gizzard shad, alewife, and even some chubs or ciscoes in the Great Lakes.

Suggested Reading – Hiodontidae

GROSSLEIN, M. D., and L. L. SMITH, JR. 1959. The goldeye, *Amphiodon alosoides* (Rafinesque), in the commercial fishery of the Red Lakes, Minnesota. U.S. Fish Wildl. Serv. Fish. Bull. 157, vol. 60: 33–41.

JOHNSON, G. H. 1951. An investigation of the mooneye (*Hiodon tergisus*). Abstr. 5th Tech. Sess. Res. Counc. Ont. p.16

KENNEDY, W. A., and W. M. SPRULES. 1967. Goldeye in Canada. Fish. Res. Board Can. Bull. 161: 45 p.

KERSWILL, C. J. MS 1937. A taxonomic and distributional study of *Amphiodon alosoides* and *Hiodon tergisus*. M.A. Thesis Univ. Western Ontario, London, Ont. 67 p. + 10 pl.

VAN OOSTEN, J. 1961. Records, ages, and growth of the mooneye, *Hiodon tergisus*, of the Great Lakes. Trans. Amer. Fish. Soc. 90: 170–174.

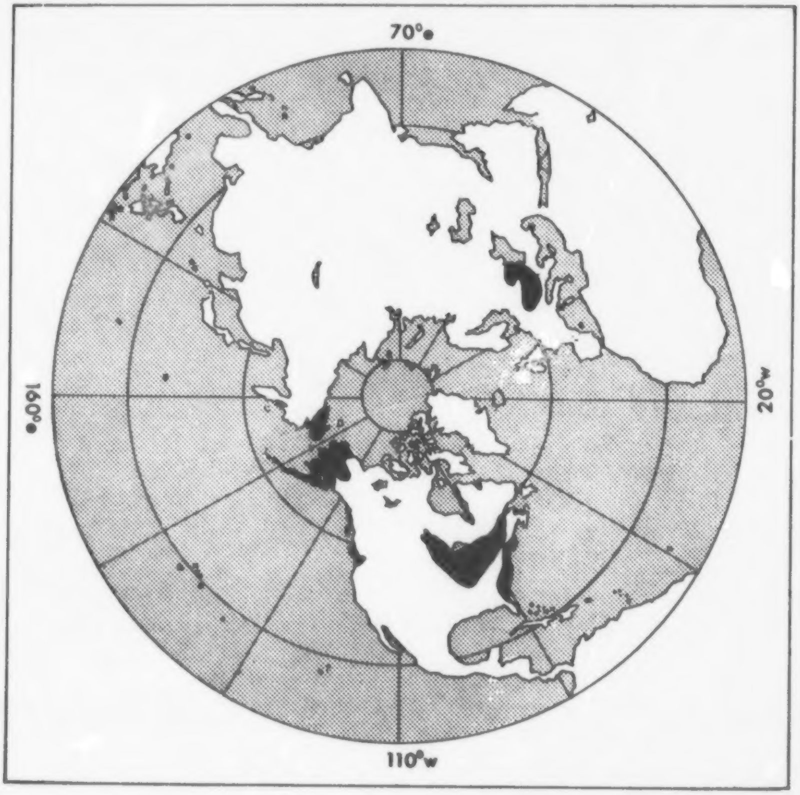
MUDMINNOW FAMILY — Umbridae

The mudminnows are small, ovate to laterally compressed fishes; with rounded caudal fins; short snouts; and square, to somewhat flattened heads. The infraorbital and nasal bones are missing. The pectoral girdle is normal and ossified, or not ossified and platelike, the mesacoracoid characteristically absent. The pectoral fins are small to large and fanlike; the pelvic fins small and abdominal. The dorsal and anal fins, subequal or anal much smaller, are far back and opposite one another. The mudminnows are physostomous and capable of breathing atmospheric oxygen.

These fishes are characteristic of small, muddy ponds, slow, vegetated streams and stagnant pools of Europe, Asia, and subtropical to arctic North America.

Now considered to include 5 species in 3 genera previously placed in 2 or 3 separate families, Dalliidae, Umbridae, and Novumbridae.

Known from the Lower Eocene to Recent in Europe and Oligocene to Recent in North America.



World Distribution of the Mudminnows

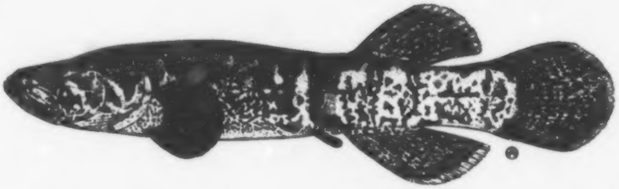
KEY TO SPECIES

1 Pelvic fin small, half as long as pectoral; anal fin of 11 or 12 rays with base about as long as base of dorsal; area between dorsal and anal fins blotched; caudal fin spotted .... ALASKA BLACKFISH, *Dallia pectoralis* (p. 338)

Pelvic fin large, as long as pectoral; anal fin of 8 or 9 rays with base about half as long as base of dorsal; area between anal and dorsal fins with vague, vertical bars; prominent vertical black bar at base of caudal; caudal fin not spotted .... CENTRAL MUDMINNOW, *Umbra limi* (p. 341)

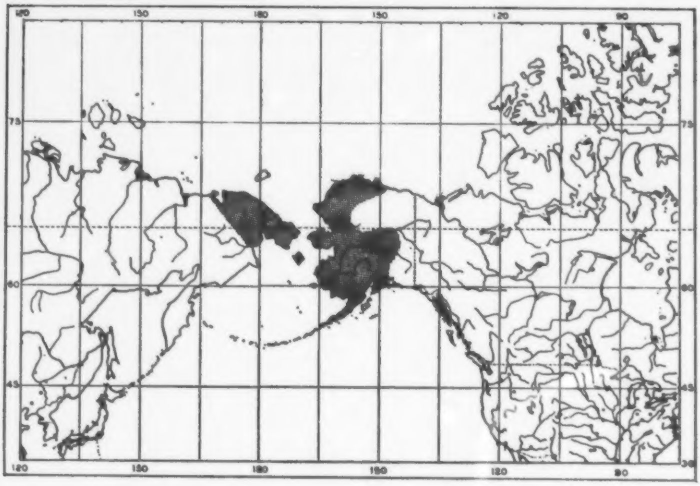
ALASKA BLACKFISH

Dallia pectoralis Bean



Description Body cylindrical, round in cross section, greatest depth (at midpoint of body) about 16% of total length; caudal peduncle moderately long, and deep, length equals depth, equals about 50% of head length; individuals usually 3–6 inches (76–152 mm) in length. Head short, about 20% of total length, depth moderate, about 40% of length; eye small, diameter about 20% of head length; snout short, about 20% of head length, pointed, lower jaw projecting slightly beyond tip of snout; mouth moderately large, maxillary extending at least to posterior edge of pupil; small but well-developed teeth on premaxillary, vomer, palatine and dentary but absent from maxillary, tongue, and basibranchial. Gill rakers short 9–12 (1–2 + 8–10). Branchiostegal rays 14–18. Fins: a single, soft-rayed dorsal far back, origin opposite origin of anal fin, length of base about equal to fin length, less than base of anal fin, edge rounded, 10–14 rays, fin height less in females; caudal broad and rounded; anal below dorsal, immediately behind anus, base longer than that of dorsal fin, about 13% of total length, height greater than base length and about equal to head length, height less in females, edge rounded, 12–16 rays; pelvics small, abdominal and close to anus, usually with 3 rays; pectorals very large, vertical, broad, round, and fanlike with wide base, 32–36 rays. Scales small, cycloid, embedded, 76–100 in lateral series; lateral line complete but pores inconspicuous. No pyloric caeca; physostomous. Vertebrae 40–42.

Colour Adults dark brown to olive-green above and on sides, with four to six dark bars and blotches or spots on sides, underside paler, marked with dark speckling; fins speckled with red-brown, vertical fins



edged with white to colourless in adults and pale red in spawning males. Young similar but paler and without white edge on vertical fins. Up to about 1 inch (25 mm) the young have three dark spots at the caudal base.

Distribution This species is restricted to arctic and subarctic fresh water in the northeastern tip of Siberia, the Bering Sea islands of St. Lawrence, St. Matthew, and Nunivak, and in Alaska.

In Alaska it extends throughout the lowlands from the central Alaska Peninsula (near Chignik) north along the arctic coast to the Colville River. It extends inland in the Yukon–Tanana River system as high as Fairbanks, Alaska. It has been introduced on St. Paul Island in the Pribilofs and Hood Lake near Anchorage.

Blackfish from the Kuskokwim River near Bethel, Alaska, were brought to Ontario in 1956 and introduced in a few farm ponds. It was hoped they could survive the drastic oxygen depletion in winter and provide recreation from these shallow ponds. The introduction was unsuccessful.

This species does not now occur in Canada but since it is the only freshwater fish occurring in Alaska that does not occur in Canada as well, it would seem foolish to exclude it from our treatment of the Canadian fauna.

Dall's 1871 discussion of *Cottus*? sp.–Blackfish is probably the earliest North American record of this species.

Biology Other than comments on the vast numbers of this fish that occurred in tiny, weed-choked pools, its use by natives, and the oft-repeated erroneous story, traceable to Turner (1886), about its ability to withstand freezing, virtually no information on the biology of this species was available prior to the work of Ostdiek and Nardone (1959) and that of Blackett (1962).

There is an upstream migration of adult blackfish in the spring into swampy potholes, coincident with a 10°–15° F (5.6°–8.3° C) rise in water temperature after the ice breaks up in May. Only small numbers of small fish are present in these pools under the ice in winter. Spawning may extend from May to August and is estimated by some to occur mainly in July. Females carry eggs of two sizes and stages of development. The ripe eggs are approximately 2 mm in diameter, the recruitment eggs 0.6–1.0 mm in diameter. Egg number (ripe) was given by McPhail and Lindsey (1970) as 100–300 and it is possible they are shed in very small numbers over a protracted period. Eggs are demersal and adhesive and doubtless adhere to the heavy vegetation of these pools. It is unlikely that a nest is built. At 54° F (12.2° C) in experimental situations, eggs hatch in about 9 days.

Growth is rapid in the first summer and the young often reach a length of 20 mm by September. Age determination by scales is possible and Blackett gave an age–length relation as follows:

Age (*years*)	Length (mean in parentheses) (*inches*)	Length (mean in parentheses) (*mm*)
1	2.0–3.6 (2.5)	52–92 (64)
2	3.0–5.7 (4.2)	78–146 (108)
3	3.7–6.5 (5.0)	96–166 (128)

Increment in growth is much smaller after the first year. Length–weight relation is curvilinear, the largest and oldest fish (males) weighed about 35 grams. Males apparently increase in weight at a slightly faster rate than females. Blackett's largest fish was 6.5 inches (165 mm) (total length?) but Bean's (1880b) original specimens included a specimen 8 inches (205 mm) in length. It is probably on the basis of this specimen that the length is most often reported as up to 8 inches. Some females reach maturity in their second year but most blackfish spawn first in their third year. McPhail and Lindsey (1970) gave maximum age as 8 years. If this is so, many females must spawn more than once.

The summer habitat is usually the weed-choked, lowland swamps and ponds of the area, but blackfish occur also in streams, rivers, and large lakes where vegetation is abundant. This species is most abundant in the tundra but does occur in forested areas, where habitat is suitable. Nothing is known of the winter habitat prior to the spring upstream migration but the species is known to be active at 39° F (3.9° C).

The blackfish is a sluggish bottom dweller and remains hidden in the vegetation most of the time. It moves about searching for food by a paddling action of the large pectoral fins. It moves up slowly on individual food items, which it takes with a quick dart. Food is largely dipterous insect larvae, ostracods, cladocerans, and snails. Fishes are not often recorded in its natural diet, but in captivity they will take small minnows. *See* Ostdiek and Nardone (1959) for a detailed analysis of habitat and food.

Very few fishes, possibly excepting sticklebacks, occur in the habitat so there are probably no predators other than bears, mink, otter, birds, and man.

Rausch (1956) described a new cestode, *Diphyllobothrium dalliae*, from this species, Blackett (1962) added a trematode *Tetracotyle* sp., and Hoffman (1967) listed Protozoa (3), Trematoda (1), Cestoda (1), Nematoda (1), and Acanthocephala (1).

This species has long been of interest to man as a result of its ability to live in vast numbers in tiny stagnant ponds where dissolved oxygen is as low as 2.3 ppm and to survive for extended periods out of the water, if moist. Interest over the years in the supposed ability of this fish to withstand freezing is traceable to Turner (1886) who said "The vitality of this fish is astonishing. They will remain in . . . grass-baskets for weeks, and when brought into the house and thawed out they will be as lively as ever. The pieces which are thrown to the ravenous dogs are eagerly swallowed; the animal heat of the dog's stomach thaws the fish out, whereupon its movements soon cause the dog to vomit it up alive. This I have *seen* . . . ." Several properly controlled experiments have shown that this species is definitely cold-adapted, can be active at very low temperatures, but cannot withstand actual freezing, or survive when bound in the ice.

Relation to man Although apparently available in vast numbers in certain places in summer and said to be rich, oily, good tasting, and yielding a good quality oil, the blackfish has never been taken commercially nor is apparently eaten by white people. It was long a staple part of the diet of native peoples in Alaska. It had always afforded them abundant food in the early spring when other types of food were not available. Nelson (1887) said they were also caught in the fall as the ice formed, packed 50–100 pounds in woven grass bags and stored frozen for the winter. He estimated 69 tons were so stored in one area alone, in one fall. It is still captured for food for sled dogs. Turner described the spruce wood traps used to catch this species and the fact that tons of the fish were taken. He stated that the natives sold the fish by the basket, and that a few cents would pay for three-fourths of a bushel. They were stored frozen in the open while cold weather prevailed, and sufficient quantity for food, or to feed dogs, was broken off when needed. They are no longer taken in such quantity for human food.

Nomenclature

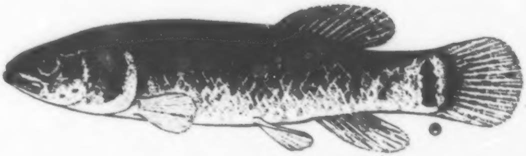
Dallia pectoralis	— Bean 1880b: 358 (type locality St. Michael's, Alaska. Holotype USNM 23498)
Cottus sp.?	— Dall 1871: 388

Etymology *Dallia* — in honour of Dr W. H. Dall, naturalist of the Alaska Telegraph Expedition; *pectoralis* — alluding to its broad, fanlike pectoral fins.

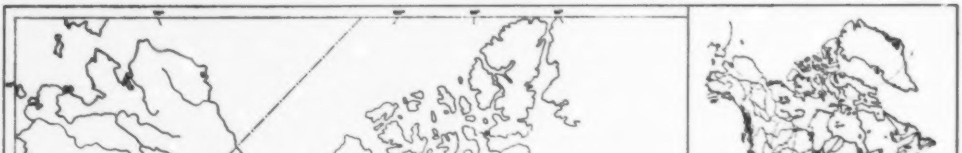
Common names Alaska blackfish, blackfish, devilfish, grassfish, Eskimo — *I-mäñ'-ûk*, Russian — *Chernaya ryba*. French common name: *dallia*.

CENTRAL MUDMINNOW

Umbra limi (Kirtland)



Description Body robust, almost round in cross section behind head, more compressed beyond dorsal fin, greatest depth (at rear of pectoral fin) 14.3–20.6% of total length; caudal peduncle long, about 20% of total length; moderately deep, almost as deep as head, about 11% of total length; individuals usually 2–4 inches (51–102 mm) in length. Head moderately long, 20.4–26.1% of total length, eye large, about 18.6–28.9% of head length, pupil black; top of head, cheeks, and opercles scaled; snout short, equal to eye diameter, 21.4–29.1% of head length, bluntly rounded; mouth moderate, premaxillary not protractile, maxillary extending to anterior edge of pupil, lower jaw projecting slightly; small villiform teeth on the premaxillary, 2–7 on the vomer, a double row on each palatine, basibranchials, and some suprapharyngeals, infrapharyngeals, and dentaries. Gill rakers 13–15 (5–6 + 8–9) short, stout, triangular. Branchiostegal rays 4 or 5 on each side. Fins: a single, soft-rayed dorsal, moderately high, fin height



about equal to head length, length of base about 20% of total length, edge square to rounded, 13–15 rays; caudal round, only slightly expanded, 12 or 13 rays; anal with origin posterior to origin of dorsal, moderately long, about 18% of total length, higher in males than in females, base length a little over 50% of that of dorsal fin, 7–9 rays; pelvics abdominal, under origin of dorsal, short but broad, rounded, 6 or 7 rays; pectorals low, vertical, broad, rounded, 14–16 rays. Scales large, cycloid, 34–37 in lateral series; no lateral line, naked neuromasts scattered over body; no pyloric caeca; physostomous. Vertebrae 35–37.

Colour Upper parts of head and body dark olive-green, through brown, to brown-black, sides mottled or marbled with dark brown, coalescing in some habitats into as many as 14, distinct or vague, vertical bars, ventral part of body yellow to white, a prominent, narrow, vertical, black bar at base of tail; all fins dusky to brownish. Colour of females at spawning time supposedly brighter than males, both with green iridescence at this time, particularly on anal fin. Young similar to adults except vertical bars inconspicuous to absent.

Systematic notes There are no apparent significant differences in meristic characters across Canada. The only proportional difference is in the relation of body depth to total length. There is an increase in body depth toward either the north or the west or in both directions.

Distribution Restricted to central North America west of the Appalachian Mountains from Quebec east of Montreal, Lake Champlain, western New York, the glaciated portion of Ohio, south to Tennessee and eastern Arkansas, north through eastern parts of Missouri (not in Kansas as usually stated), Iowa, the Dakotas, to southern Manitoba and Ontario.

In Canada it occurs south of a line from about Trois Rivières, Que., through Sault Ste. Marie, and in the Nelson River drainage of southwestern Ontario and southern Manitoba.

Distribution in Ohio and other states said to be shrinking as a result of siltation.

Biology Most of the solid information on the biology of the mudminnow comes from a study by Peckham and Dineen (1957) in Indiana, and an unpublished thesis by Westman (1941) on a New York State population. Other information is scattered. Virtually no information is available for Canada except feeding data by Keast and Webb (1966).

Mudminnows spawn in early spring. A migration of pairs of mudminnows upstream and into shallow water was reported in the past, but later authors noted only lateral movement from the main stream channel to flooded benches after rains in March. Westman gave spawning in New York as April 18–25, at a water temperature of 55.4° F (13° C). Spawning in Ontario takes place in mid- to late April, as judged by the large number of young 18–23 mm in total length, taken on June 1 in Jones Creek, Leeds County, Ont., when the water temperature was 55° F (12.8° C). Early reports of these fish running up swift hillside brooks to spawn seem contrary to more recent information. However, Toner (1943) stated that they penetrated the springs that are the headwaters of the creeks in which they were found. Water temperature at spawning time has been given as 60° F (15.6° C), but this seems high. Mature females from 2.0 to 3.7 inches (52–94 mm) long contain 220–2286 eggs, 1.6 mm in diameter. All ripe eggs in the ovaries appear to be much the same size, so spawning period may be short. No nest building is reported for this species except by Westman who said the female guards the nest, in contrast to the other species in the genus. Most say that in this mudminnow the eggs are laid singly, are adhesive, and stick to the heavy vegetation of the habitat. No care is provided eggs or young. Eggs hatch in about 6 days and the young when hatched are about 5 mm long. Up to the time they are 25 mm long the young have a notochordal lobe above the developing caudal fin, similar to that in *Lepisosteus*. It is thought that it helps orient the fish before feeble movement takes place with the poorly developed fins. The young move back to the main stream when they are about 1.2 inches (30 mm) in length. Fish (1932) gave details of the early development of young and a photograph.

Details of growth with age are hard to determine as the scales apparently do not give an accurate age estimate. Size frequency was used by Applegate (1943) to estimate that two age-groups were represented in individuals up to 100 mm in length. Young-of-the-year are 0.7–1.4 inches (19.5–37.5 mm) in standard length and 1-year-old fish are 1.4–3.5 inches (37.5–90.0 mm). One or more of the very low modes in Applegate's size frequency data, distributed about 2.3 inches (58 mm), 3.1 inches (79 mm), and 3.9 inches (99 mm) probably represent older fish, especially since Westman (1941) cited four age-groups and gave 3.3 inches (85 mm) as size at age 4. Age–length relation, from otoliths, given by Westman, does not differ greatly from that of Peckham and Dineen and is as follows:

Age (*years*)	Mean TL (*inches*)	 (*mm*)
0 (Sept.)	0.9–2.1	25–53
1	2.0	51
2	2.5	64
3	3.0	76
4	3.3	85

Westman also suggested that females grew faster than males. Males mature at age 1, some females mature at age 1 but most at age 2. The larger fish are females, which probably live longer than males. Trautman (1957) gave 5.2 inches (132 mm) as maximum size. It is interesting that specimens as large as this were obtained from Jones Creek, Leeds County, Ont. This size is 45 mm greater than Westman's 4-year-old mudminnows, a differential greater than that between his 1- and 4-year-old fish. The growth increment between

3 and 4 years in Westman's data is 9 mm. This would suggest either that mudminnows live at least to 7 or 9 years of age or that his age interpretation was in error. No age in excess of 4 has been suggested in the literature. It would seem likely that at least some females spawn several times.

The summer habitat of this species is usually heavily vegetated ponds or pools of small creeks, where the bottom has a thick layer of organic material. These pools often become isolated, stagnant, and, in Ontario, as warm as 84° F (28.9° C) in August. It occurs elsewhere though, as Toner (1943) said they were found further upstream than any other fish, penetrating to the springs and swamps of the uplands. He said they were taken from 31% of the warm brooks, 19% of the creeks, and 9% of the bog creeks. Hallam (1959) stated that in a stream situation in Ontario they were associated more often with such cool-water forms as *Cottus bairdi* and *Salvelinus fontinalis* than they were with warmwater species such as *Micropterus dolomieui* and *Ambloplites rupestris*. The spawning site on flooded benches possibly protects the newly hatched young but also subjects them to possible mortality when the water recedes and benches dry up.

Mudminnows have usually been described in early reports as burrowing quickly into the mud, tail first, to escape predation, or to survive drought conditions, and as hibernating in the mud in winter. Later observations show that they do flee into the thick detritus and flocculent ooze but do not burrow into the mud. Black (1945) showed that the swim bladder does have a respiratory capability and that mudminnows do gulp air at the surface when oxygen is low. At times, however, numbers of them are killed by low oxygen in winter. Peckham and Dineen showed that throughout the winter they were active and fed under the ice.

Movements upstream and downstream were, in the past, thought to be extensive. Peckham and Dineen (1957) noted only lateral movement within the habitat and on to the flooded stream banks to spawn. The young move off these benches back into the main pond or stream when about 1 inch (30 mm) in length. None were seen or captured in nets in a study area in Ontario on April 26, 2 weeks after the ice melted, when water temperature was 46° F (7.8° C). By May, however, when water temperature was 56° F (13.3° C), mudminnows were plentiful and possibly spawning.

Mudminnows are carnivorous and feed generally on the bottom. Most of the time they remain motionless in cover and move up on individual larger food items by means of a quick dart using the whole body, or slowly on small bottom items by paddling with the pectoral fins. The food of young mudminnows is largely ostracods and some newly hatched snails, but insect larvae and adults, molluscs, amphipods, isopods, and arachnids are the principal food after 20 mm. Fish rarely appear in the diet and Peckham and Dineen, who gave a detailed quantitative and qualitative food analysis, listed only a single blacknose dace and two unidentified fishes.

Mudminnows are preyed on by a variety of larger stream forms including grass pickerel, chain pickerel, northern pike, sunfishes, and catfishes. What seemed like food selection occurred in a predator–prey relation between grass pickerel and mudminnows in a particular Ontario stream (Crossman 1962b). Birds, muskrats, and foxes have been reported to eat them. Mudminnows probably compete for food with a wide variety of stream-dwelling minnows as well as with the invertebrate-feeding young of species that, when larger, may be their predators.

Hoffman (1967) listed 26 parasites as follows: Protozoa (3), Trematoda (14), Cestoda (1), Nematoda (3), Acanthocephala (4), Crustacea (1). His list did not include the trematode *Clinostomum complanatum* reported by Peckham and Dineen.

Relation to man This species is a small, rather secretive inhabitant of small creeks and isolated ponds. It bears little relation to man other than serving as bait for sport fishes and as food for other species of little apparent interest to him. Mudminnows are hardy and capable of taking in atmospheric oxygen, so they are considered good bait fish. This species enters into the baitfish definition for regulations in Ontario and they are sold as such in Ontario, Quebec, and the United States. They also make very attractive and interesting aquarium fishes.

Nomenclature

Hydrargira limi — Kirtland 1841a: 277 (type locality Yellow Creek, Mahoning Co., Ohio. (according to Trautman 1957))
Hydrargyra fusca — Thompson 1842: 137
Hydrargyra atricada — DeKay 1842: 220
Hydrargyra atricauda — Fortin 1866: 76

Etymology *Umbra* — a shade, or dark, possibly referring to its habitat, they were once thought to inhabit caves; *limi* — mud.

Common names Central mudminnow, western mudminnow, mud minnow, Mississippi mud-minnow, mudfish, dogfish. French name: *umbre de vase.*

Suggested Reading – Umbridae

APPLEGATE, V. C. 1943. Partial analysis of growth in a population of mudminnows, *Umbra limi* (Kirtland). Copeia 1943: 92–96.

BLACKETT, R. F. 1962. Some phases in the life history of the Alaskan blackfish, *Dallia pectoralis*. Copeia 1962: 124–130.

CHAPMAN, W. M. 1934. The osteology of the haplimous fish *Novumbra hubbsi* Schultz with comparative notes on related species. J. Morphol. 56: 371–405.

DINEEN, C. F., and P. S. STOKELY. 1954. Osteology of the central mudminnow, *Umbra limi*. Copeia 1954: 169–179.

GILL, T. N. 1903. A remarkable genus of fishes — the umbras. Smithson. Misc. Collect. 45: 295–305.

OSTDIEK, J. L., and R. M. NARDONE. 1959. Studies on the Alaskan blackfish *Dallia pectoralis*. I. Habitat, size and stomach analyses. Amer. Midland Natur. 61: 218–229.

PECKHAM, R. S. MS 1955. Ecology and life history of the central mudminnow, *Umbra limi* (Kirtland). Ph.D. Thesis. Univ. Notre Dame, Notre Dame, Ind. 71 p.

PECKHAM, R. S., and C. F. DINEEN. 1957. Ecology of the central mudminnow, *Umbra limi* (Kirtland). Amer. Midland Natur. 58: 222–231.

SCHULTZ, L. P. 1929. Description of a new type of mudminnow from western Washington with notes on related species. College Fish. Univ. Wash. Publ. Fish. 2(6): 73–81.

STARKS, E. C. 1904. A synopsis of characters of some fishes belonging to the order Haplomi. Biol. Bull. (Woods Hole) 7: 254–262.

1905. The osteology of *Dallia pectoralis*. Zool. Jahrb. Abt. Syst. 21: 249–262.

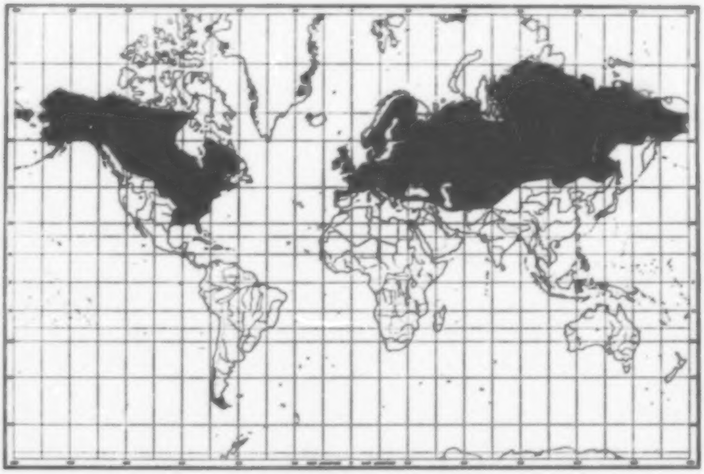
WESTMAN, J. R. MS 1941. A consideration of population life-history studies in their relation to the problems of fish management research, with special reference to the small-mouthed bass, *Micropterus dolomieu* Lacépède, the lake trout, *Cristivomer namaycush* (Walbaum), and the mudminnow, *Umbra limi* (Kirtland). Ph.D. Thesis. Cornell Univ., Ithaca, N.Y. 182 p.

PIKE FAMILY — Esocidae

Body elongate, laterally compressed; tail forked; dorsal and anal fins far back, equal to subequal in size, and situated opposite one another. Head large; snout elongate, flat, and somewhat like a duck's bill. Jaw articulated behind the posterior edge of orbit. Teeth on jaws, large and prominent. Large patches of cardiform teeth on vomer, palatines, and tongue. Inframandibular present in contrast to mudminnows. Gill rakers reduced to patches of sharp denticles. Pectoral fins low; pelvic fins abdominal. Mesocoracoid absent from pectoral girdle (the so-called simple shoulder characteristic, previously used to classify the pikes and mudminnows in the order Haplomi). The pikes are physostomous, but there is no known ability to breathe atmospheric oxygen.

Small to large fishes of small streams, ponds, rivers, lakes, and to a minor degree, brackish waters, from subtropical to arctic North America and Eurasia. One genus of 5 species. One species, *Esox lucius*, circumpolar, 1 endemic to Siberia, and 3 endemic to eastern North America.

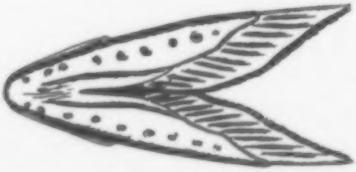
Known from the Middle Eocene to Recent in Eurasia and Pliocene to Recent in North America.



World Distribution of the Pikes

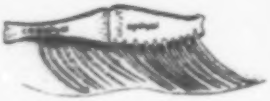
KEY TO SPECIES

1 Submandibular pores 10 or more; cheeks and/or opercula not fully scaled 2



Submandibular pores 8 or fewer (rarely 9); both cheeks and opercula more or less fully scaled 3

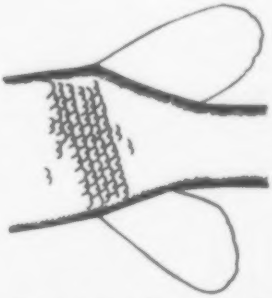
2 Submandibular pores 12–20; branchiostegal rays 16–19 on each side, most often 8 + 10 (8 on ceratohyal, 10 on epihyal) on each side; pattern silvery or light ground colour with dark spots, blotches, or vertical stripes; neither cheeks nor opercula completely scaled ..... MUSKELLUNGE, *Esox masquinongy* (p. 363)



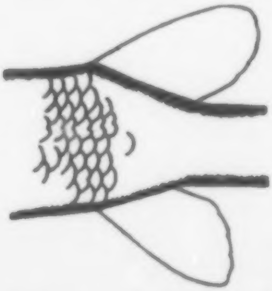
Submandibular pores 10 or 11 (rarely 9); branchiostegal rays 13–16, most often 7 + 8 on each side; pattern dark ground colour with white to yellow, wavy, vertical stripes in young, or horizontal rows of yellow bean-shaped spots in adults; cheeks full scaled, opercula not so ..... NORTHERN PIKE, *Esox lucius* (p. 356)

3 Submandibular pores 7 or 8 (rarely 9) and branchiostegal rays 14–17, most often 6 + 9 (6 on ceratohyal, 9 on epihyal) on each side; pattern dark ground colour with pale wavy, vertical stripes in young, and golden chainlike markings in adults ..... CHAIN PICKEREL, *Esox niger* (p. 370)

Submandibular pores 7 or 8 and branchiostegal rays 11–13 on each side 4



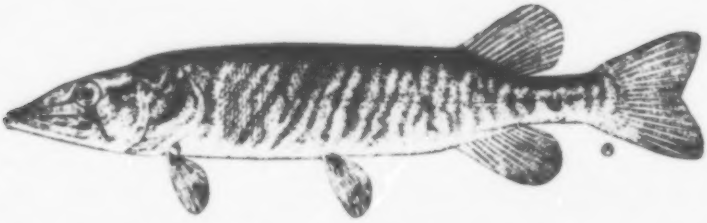
4 Branchiostegal rays usually 5 + 7 or 5 + 8 on each side; snout short, convex in upper profile; cardioid scales between pelvics more than 5, and more than 5 in a line from origin of anal fin to dorsal surface; lower fins red to orange ..... REDFIN PICKEREL, *Esox a. americanus* (p. 348)



Branchiostegal rays usually 4 + 7 or 4 + 8 on each side; snout longer and concave in upper profile; cardioid scales between pelvics fewer than 5, and fewer than 5 in a line from origin of anal fin to dorsal surface; lower fins dusky to yellow-green ..... GRASS PICKEREL, *Esox a. vermiculatus* (p. 352)

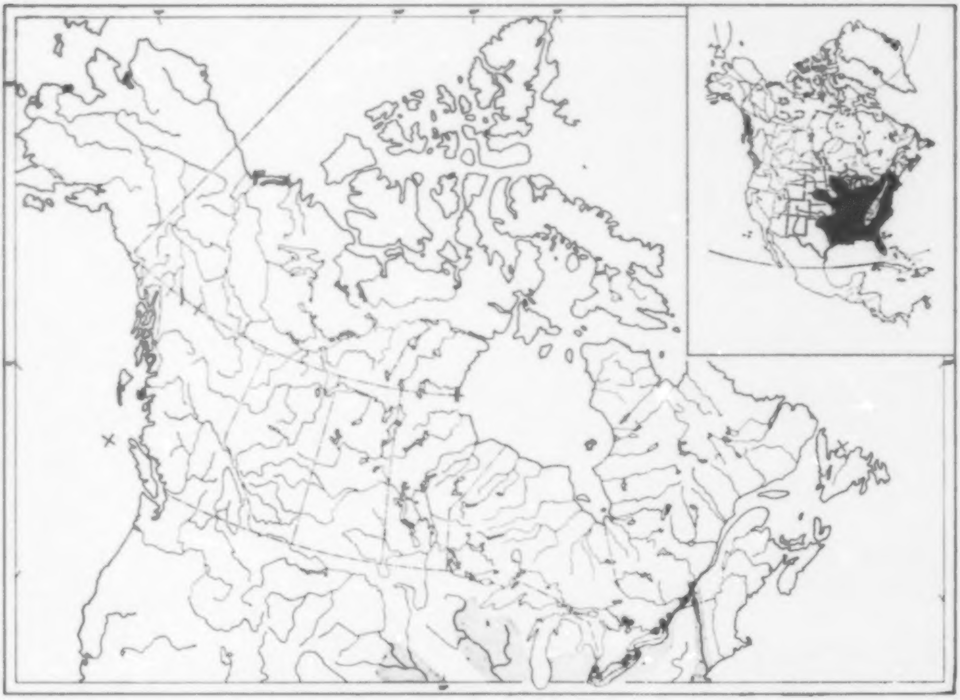
REDFIN PICKEREL

Esox americanus americanus Gmelin



Description Body long, cylindrical, little compressed laterally, flattened dorsally before dorsal fin, greatest depth (between paired fins) 13.6–18.3% of total length, body width 7.7–10.5% of total length, cross section almost round; caudal peduncle length 13.1–14.8% of total length, caudal peduncle depth 13.6–18.3% of total length. Individuals are usually 6–8 inches (152–203 mm) in length. Head moderately long, 24.2–25.7% of total length, flat and naked on top, broad, interorbital width 20.2–23.1% of head length; cheeks and opercula fully scaled; eyes high, moderately large, eye diameter 13.4–14.5% of head length; snout very short, length 33.8–38.6% of head length and 70.9–83.3% of postorbital head length, convex, not concave, between eye and tip and very broad; mouth large, horizontal, maxillary reaching at least to middle of pupil or to suborbital bar and sometimes to the posterior edge of pupil; short, sharp, recurved cardiform teeth along the premaxillary and in patches on tongue, basibranchials, last two pharyngobranchials, vomer, and palatines; large, strong canines on head of vomer inner edge of palatine patches and on the dentaries, those on dentaries flattened with sharp edges as well as tips, other canines pointed but round and peglike. Lower jaw slightly longer than snout, undersurface pierced by 4 pores on each side (rarely 3 or 5 on one side only). Gill rakers reduced to patches of sharp, radiating denticles on both sides of arches. Branchiostegal rays 12 or 13 on each side, usually 5 or 6 on ceratohyal and 7 rarely 8 on epihyal. Fins: dorsal 1, soft rayed, far back, distance from nape (or occiput) to dorsal origin 43.8–47.8% of total length, base shorter than height of fin, less than 50% of head length, upper edge rounded, 15–18 principal rays; caudal shorter, forked, tips rounded; anal under dorsal, base shorter than that of dorsal, height less than that of dorsal, edge rounded, 13–17 principal rays; pelvics abdominal, low, at midpoint of body, rounded, 8 or 9 rays; pectorals low, arising under edge of opercular flap, rounded, 14 or 15 rays. Scales rather small, cycloid, 102–116 in lateral series; lateral line complete, lateral line scales notched not pierced or tubed, many notched scales bordering sensory cells elsewhere on body, 7–16 such scales in triangle between pelvic fins, 13–22 in the row from origin of anal to dorsal surface; intestine long and undifferentiated, no pyloric caeca. Physostomous. Vertebrae 49 or 50.

Colour Adult pattern first appears at about 4–6 inches (102–152 mm) length. The dorsal surface of back, head, and upper sides are uniform light brown to olive-green. There is a very inconspicuous pale, mid-dorsal band from the nape to the origin of the dorsal fin. The sides are marked by 20–36 olive to dark brown, wavy, vertical bars separated by paler extensions of what had been a lateral band in the young of about 4 inches (100 mm) in length. The pale area between adjacent bands is narrower than the bands. The ventral surface is pale amber to milky white. Suborbital and preorbital black bars pronounced, suborbital recurved, off vertical, postorbital horizontal, lateral edges of jaws heavily pig-



World Distribution of *Esox americanus* (both Subspecies)

mented as is tip of area between lower jaws, and isthmus. The amount and intensity of submandibular pigment (greater in females) can be used to separate the sexes with about 75% accuracy. The pupil of the eye is yellow to yellow-green. The dorsal fin is darkly pigmented, all others are bright amber to orange in Canada, orange to red elsewhere, hence the common name. Young-of-the-year at 2-inches (50-mm) length are uniformly darker brown almost to the level of the paired fins without apparent interruption of light pigment. From 4 inches (100 mm) in length, vertical extensions of an inconspicuous, light, midlateral band begins to break the dark sides into vertical dark bars.

Systematic notes This species at different times has been considered a separate species distinct from the grass pickerel, and as the typical form of which the grass pickerel is a subspecies. We treat the two here as subspecies following the opinion expressed by many authors and documented by Crossman (1966). Populations in the Gulf states from Mississippi to Florida possibly constitute intergrades of the two subspecies.

Distribution Restricted to fresh water and infrequently brackish water of eastern North America. This is characteristically a fish of the coastal plain of the eastern United States. Its distribution extends from the St. Lawrence River (Lac St. Pierre) south through the Richelieu–Champlain–Hudson system into New York, east through southern Vermont and New Hampshire to Long Island, south along the coastal plain east of the Allegheny–Appalachian mountains to Georgia. The species as a whole continues as intergrades with the grass pickerel, south to Lake Okeechobee, Florida, and west to near the Mississippi–Louisiana border where it is replaced by the grass pickerel. It has been introduced west of the mountains in Maryland and possibly Pennsylvania.

In Canada the distribution is limited to Quebec. Redfin pickerel occur in the St. Lawrence River, in the immediate area of Lac St. Pierre, the Richelieu and its tributaries including Lake Champlain, Yamaska River, St. Francois River, the Godefroy River, and Lac St. Paul. It is isolated from the other subspecies, the grass pickerel, by about 75 miles, part of which is badly polluted habitat around Montreal. This barrier may prevent contact of the two forms.

Its distribution in the United States does not seem to be shrinking but the numbers of this species in the St. Lawrence in and around Lac St. Pierre, seem to have been drastically reduced as a result of possible habitat changes subsequent to the construction of the St. Lawrence Seaway.

Its presence in Canada was first discovered in 1944 (Cuerrier 1947). Since it was found in Canada so recently and since it still has such a limited distribution here, it seems likely that the man-made connection between the Hudson River and the Lake Champlain–Richelieu River system built in 1819, rather than the Lake Champlain–Hudson River discharge of the Great Lakes in glacial times, provided the access to Canadian waters.

Biology Unlike its counterpart the grass pickerel, virtually nothing is known of the biology of the redfin pickerel in Canada. Other than sketchy discussions in Kendall (1917) and Weed (1927) there was little concrete biological data for this species until a 1959 study in North Carolina (Crossman 1962c).

The redfin pickerel is basically a spring spawner, but, as is the case for the other pickerels, adequate investigation may indicate fall spawning as well. Spawning takes place in spring when water temperatures approach 50° F (10° C) probably in April in Canada, and spawning may take place over a period of 2 weeks in the north or as long as a month in the south. No record of spawning activity is available but it undoubtedly spawns in the very shallow, heavily vegetated flooded margins of the stream habitats. No nest is built; the eggs are broadcast and abandoned to adhere to the bottom and vegetation. Average total egg number is 3716 of which 186–542 are mature. This is approximately one-third the total number contained in a grass pickerel of equal size. Eggs in two other recruitment stages are present with the mature eggs, at any time prior to spawning. Eggs are transparent, golden yellow in colour, and average 1.9 mm in diameter. They hatch in 10–14 days and the inactive young, which at this time are 5.8–6.1 mm in total length, exist on the yolk for 10–12 days before they commence active feeding. Mansueti and Hardy (1967) illustrated and described larval changes in the Chesapeake Bay region. Growth is very rapid in the first summer, as much as 20–30 mm in each month. The age–length relation for redfins in North Carolina is as follows:

Age	Mean FL		Range of FL	
(years)	*(inches)*	*(mm)*	*(inches)*	*(mm)*
1	4.3	111.1	3.6–5.0	92–129
2	5.5	140.3	4.6–6.3	117–162
3	7.0	177.9	5.5–8.0	140–205
4	8.4	210.5	7.5–9.5	192–241
5	9.2	235.0	8.3–10.7	210–273
6	11.2	285.0	11.2	285

Growth in length seems to be straight line in nature, continuous and sexually dimorphic. Females grow faster, live longer and, achieve greater maximum size. Length–weight relation is curvilinear. Maximum size in Canada would appear to be approximately 12.3 inches (312 mm) total length. Maximum length on Long Island has been given by Greeley (1938) as 13 inches (330 mm). A record of 19 inches (483 mm) given by Westman (1952) was probably a redfin pickerel × chain pickerel hybrid.

Maximum age is probably 5–7 years in Canada.

The habitat of redfin pickerel is sluggish, heavily vegetated, usually acid water streams. They occur less frequently in ponds and in the weedy backwaters and quiet bays of larger lakes and rivers.

Redfin pickerel, like the other members of the family, are basically piscivorous predators. Food of young-of-the-year (under 50 mm) is entirely invertebrates such as cladocerans, amphipods, isopods, and the immature stages of such aquatic insects as dragonflies, mayflies and caddisflies. Larger fish feed mostly on other fishes, probably a wide spectrum of warmwater species, but minor amounts of aquatic insects are part of the diet as well.

Where they occur together this species is probably preyed on by larger sunfishes, pikes, perches, and possibly catfishes. As young, they compete for food with other fishes that feed on invertebrates. As adults, they compete with a wide variety of piscivorous predators. Some competition and predation may be limited by the nature of the habitat.

The redfin pickerel hybridizes in nature with the northern pike and the chain pickerel and intergrades with the grass pickerel in the south. The last two hybrids are fertile, the first is sterile (Crossman and Buss 1965).

Hoffman (1967) summarized the parasites of this species as follows: Protozoa (1), Trematoda (3), Cestoda (2), Nematoda (1).

Relation to man This species is small but often locally abundant. In the past it appeared regularly in the fresh-fish markets of the eastern United States and was said to be worthwhile food. Until recently it was caught and marketed, in small quantities, by commercial fishermen around Lac St. Pierre in Quebec. It appears no longer to be abundant enough to do so there.

On the coastal plain of the United States it is often sought after specifically by anglers with light rods and very small spinners. It is said to provide good sport. Older literature attested to its gamey nature and the fact that it would leap out of the water after artificial flies. There is no record of anglers fishing specifically for it in Quebec. They do not often angle in the type of habitat in which it occurs.

Nomenclature

Esox lucius β americanus	— Gmelin 1788: 1390 (type locality vicinity of New York City)
Esox americanus	— Cuerrier 1947: 62
Esox americanus americanus	— Legendre 1952: V

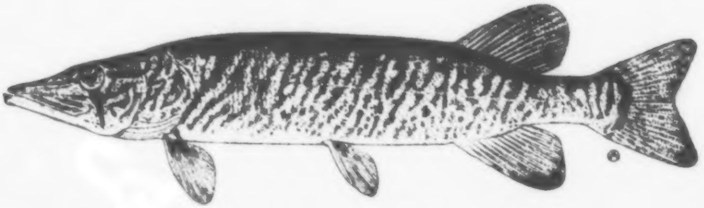
Etymology *Esox* — an old European name for the pike; *americanus* — from America.

Common names Redfin pickerel, banded pickerel, trout pickerel, grass pickerel, mud pickerel, bulldog pickerel, pickerel, red-finned pike (*see* Weed 1927: 42–43 for list). French common name: *brochet d'Amérique*.

The common name pickerel (the diminutive of pike) should be restricted to the three small members of the pike family, redfin, grass, and chain pickerels. Pickerel is a misnomer when applied to the walleye, a member of the perch family.

GRASS PICKEREL

Esox americanus vermiculatus Lesueur



Description Body long, cylindrical, little compressed laterally, somewhat flat dorsally, shallow, greatest depth (between paired fins) is 12.1–17.4% of total length, cross section almost round; caudal peduncle moderately long 14–16% of total length, and narrow; depth 5.6–6.3% of total length. Individuals are usually 6–8 inches (152–203 mm) in length. Head moderately long, 27.9–31.4% of total length, flat and naked on top, moderately broad; interorbital width 20.5–23.6% of head length; cheeks and opercula fully scaled; eyes high, moderately large, 13.4–16.0% of head length, snout short, 37.0–41.6% of head length, 80.2–94.0% of post-orbital head length, rounded and concave on top, snout only moderately broad; mouth large, horizontal, maxillary usually not reaching beyond middle of pupil nor to the suborbital bar; short, sharp, recurved cardiform teeth along the premaxillary and in patches on tongue, basibranchials, last two pharyngobranchials, vomer, and palatines; large, strong canines on head of vomer, inner edge of palatine patches and on the dentaries, those on dentaries flattened with sharp edges as well as tips, other canines pointed but round and peglike; lower jaw slightly longer than snout, undersurface of lower jaw usually pierced by 4 pores on each side (sometimes 3 or 5 on one side only). Gill rakers reduced to patches of sharp, radiating denticles on lateral and medial surfaces of arches. Branchiostegal rays 10–14 on each side, usually 12, 5 on the ceratohyal, 7 on the epihyal. Fins: dorsal 1, soft rayed, far back, distance from occiput (or nape) to dorsal origin 42.0–44.8% of total length, base shorter than height of fin, less than 50% of head length, upper edge square to slightly rounded, 14–17 principal rays; caudal moderately long, deeply forked, tips rounded; anal directly under dorsal fin, near anus, base shorter than that of dorsal, height less than that of dorsal fin but greater than snout length, edge more rounded than dorsal, 13–15 rays; pelvics abdominal, low, at midpoint of body, rounded, 9 or 10 rays; pectorals low, arising under edge of opercular flap, rounded and paddle-like, 14 or 15 rays. Scales rather small, cycloid, 97–118 in lateral series; lateral line complete, lateral line scales notched not pierced or tubed, single notched scales bordering sensory cells scattered elsewhere on body, fewer than 3 such scales in the triangle between the pelvic fins, no more than 5 in the row from origin of anal to dorsal surface; intestine long and undifferentiated, no pyloric caeca. Physostomous. Vertebrae 42–47.

Colour Adult pattern first appears at about 5 inches (130–140 mm) in length. The dorsal surface and upper sides are uniform pale to dark green, there is a rusty brown mid-dorsal stripe, the sides show 15–23 olive to black, thin, wavy, vertical bars separated by lightly pigmented extensions of what had in the young been a prominent golden green lateral band. The pale area between adjacent bars is wider than the bars. The ventral, vertical, suborbital and horizontal, preorbital, black bars obvious, sometimes postorbital, horizontal bar obvious; lateral edges of both jaws lightly pigmented; the pupil is yellow; the leading edge of all fins is black, the rest of the fins dusky to amber.

Young-of-the-year up to about 4 inches (100 mm) are much darker; they have a prominent golden mid-dorsal stripe from the tip of the snout to the origin of the dorsal fin, the flanks are marked with two long, dark green to black horizontal areas separated by a golden green, wide, midlateral band; the ventral surface is buff to white. (*See* Crossman 1962a, for more details.)

Systematic notes This species has at different times been considered a full species, *Esox vermiculatus*, and a subspecies of the redfin pickerel *Esox americanus*. We treat it here as a subspecies, *E. a. vermiculatus*, following the opinion expressed by many authors and documented by Crossman (1966). Populations in the Gulf states from Mississippi to Florida possibly constitute intergrades with the redfin pickerel *E. a. americanus*.

Distribution *See* map for species included in redfin pickerel, *E. a. americanus*. Restricted to the fresh waters of central North America, mainly in the Mississippi and Great Lakes drainages. The range extends from near the confluence of the Ottawa and St. Lawrence rivers south, west of the Allegheny Mountains, in the Lake Ontario and Finger Lakes drainages of New York, through the western part of the states from Pennsylvania to Louisiana, west in Gulf of Mexico drainages to the Brazos River in eastern Texas, north through the eastern parts of Oklahoma, Kansas, Iowa, to southeastern Wisconsin and southern Michigan to the lower Great Lakes in Ontario. Populations in northeast Nebraska are relicts of a wider distribution in the past. Introduced in Colorado, Washington, and California.

In Canada it is limited to tributaries of the St. Lawrence River and Lake Ontario as far west as Belleville, absent from there to the lower Niagara River, present in tributaries of the upper Niagara River, Lake Erie, Lake St. Clair, and lower Lake Huron. An isolated population in the Severn River–Muskoka Lakes area (Georgian Bay drainage) may be a relict or the result of unintentional introduction.

Previously more abundant and more widely distributed in the United States, its distribution was curtailed after 1900 as a result of drainage, loss of vegetation, and siltation.

The earliest recorded capture of grass pickerel in Canada is that of Reighard (Hubbs and Brown 1929) in Long Point Creek in 1899.

Biology The grass pickerel is not well known in Canada. It is moderately abundant wherever it occurs but is usually mistaken for the young of northern pike. The following information is based largely on a study of this species in Jones Creek, Leeds County, Ont. (Crossman 1962a).

Grass pickerel, like the other esocids, are basically spring spawners, but the evidence of low intensity fall spawning is available for this species in Michigan, Oklahoma, Wisconsin, and Ontario. It is therefore probable that changing water temperature, upward in spring, downward in fall, is the stimulus to spawning, not just the increase in temperature. In spring adults proceed upstream and on to flooded stream margins or marshes where vegetation is plentiful. This movement takes place shortly after the ice is gone, and male grass pickerel, which precede females, may be the first species to move up the streams. Spawning takes place in late March to early May when water temperature is around 45°–53° F (7.2°–11.7° C). The spawning behaviour has not been observed, but it is assumed it is the same as in the other esocids. No nest is built; the eggs are broadcast and abandoned; they are demersal, slightly adhesive, and adhere to the vegetation. Eggs of three developmental stages are present in the ovaries and total egg count has been estimated at 15,732 for a 6.2-inch (157-mm) female in Michigan. Of these, about 800 were ready for spawning and 4000 and 11,000 were in two different recruitment stages. Mature eggs are transparent amber to yellow in colour and about 1.4 mm (to 2.5 mm elsewhere) in diameter. Eggs hatch in 11–15 days at water temperatures 46°–48° F

(7.8°–8.9° C), the young, at this time are 6.2 mm long, are inactive, remain near the bottom possibly attached to vegetation, and live 10–14 days on the yolk. After that time, they begin active feeding. Growth is rapid and by early June the young are 1.0–1.4 inches (26–36 mm) in length. Hubbs (1921a) gave growth per day as 0.96 mm. By mid-September average length for Jones Creek young was 3.4 inches (87.9 mm). Age can be interpreted from the scales. Growth seems continuous and straight-line in nature, faster for females, which live longer and have a greater potential maximum size. Over ages 1–6, annual increment varies from 30 to 14 mm. Age–length relation for Jones Creek grass pickerel is as follows:

Age	Range of FL		Mean	
(years)	*(inches)*	*(mm)*	*(inches)*	*(mm)*
1	1.0–5.0	26–126	4.0	103.0
2	4.0–6.3	102–160	5.1	131.8
3	4.9–8.0	124–205	6.5	166.0
4	4.9–8.4	124–215	7.1	108.4
5	6.7–9.2	170–235	7.9	201.5
6	7.7–10.2	196–259	9.0	229.3
7	9.9–10.6	252–269	10.2	260.0

Sexual maturity is attained in females at a minimum of 6.2 inches (157 mm) fork length and by males at 5.5 inches (141 mm), which is usually at 2 years of age.

Maximum age in Canada would appear to be 6 or 7 years. Maximum size in Canada, a female from the Severn River populations, is 12.9 inches (328 mm) total length and a weight of 7.3 ounces (204 g). Trautman (1957) recorded maximum size in the United States as 15 inches (381 mm) in length and 14 ounces (397 g) in weight.

In Canada, the grass pickerel is a resident of small, slow moving, muddy, heavily vegetated lowland streams and the small pondlike expansions of the streams (often isolated) or overflow ponds of larger streams. It populates such streams, wherever habitat is suitable, anywhere from the mouth to the headwaters. More rarely it is found in quiet, weedy bays of lakes. The tolerance level of oxygen concentration has been recorded as 0.4–0.3 ppm in Michigan. The range of *p*H in Canadian habitats is 8.32–6.26.

The final preferred temperature was experimentally determined as 78° F (25.6° C); maximum temperatures of some habitats are as high as 84° F (28.9° C), and cruising speed was demonstrated experimentally to increase with increased acclimation temperature. The grass pickerel is therefore high-temperature adapted and this enables it to be successful in the conditions of high temperature, drastic decrease in water level, and minimum flow typical of its habitat. Young-of-the-year live in the shallows along the shore, but older fish are found in the deeper portions of the streams and ponds.

Food of very young grass pickerel (to 50 mm total length) is cladocerans, amphipods, osterocods, isopods, and immature or adult insects from the orders Diptera, Plecoptera, and Hemiptera. In the size range 2–4 inches (50–100 mm) they begin to prey on fishes, but the diet is mainly Trichoptera, Odonata, and crayfish. Beyond 4 inches (100 mm) the diet is almost exclusively fish and crayfish, but dragonfly nymphs form part of the food of even the largest individuals. *See* Crossman (1962a) for a complete analysis of stomach contents. In the Jones Creek habitat, 22 species of fishes were present, but grass pickerel fed on only 9 species in the following descending order of importance: central mudminnow, golden shiner, grass pickerel, white sucker, pumpkinseed, common shiner, creek chub, yellow perch, johnny darter. There was some evidence of selection of mudminnow over other more abundant species of fish (Crossman 1962b). Cannibalism was not extensive.

A broad complex of warmwater species (24 in Jones Creek) is usually associated with the grass pickerel. As young-of-the-year, they compete with most of them for food; as larger individuals they compete for food with other piscivorous predators such as catfishes, sunfishes, and the yellow perch. In turn, the young grass pickerel are preyed on by these same piscivorous predators, including grass pickerel to a slight extent. The adults may have few predators as the habitat largely precludes predation by birds and mammals.

The following parasites were listed by Crossman (1962a) for the Jones Creek population: Fungi — *Saprolegnia parasitica*; Protozoa — Myxosporidia, *Scyphidia micropteri, Trichodina renicola;* Trematoda — *Macroderoides flavus, Azygia angusticauda, Centrovaruim lobotes, Crassiphiala bulboglossa*; Cestoda — *Proteocephalus pinguis*; Nematoda — *Spinitectus gracilis;* Mollusca — glochidia of *Scyphidia micropteri*. Only protozoan parasites seemed dense enough to endanger the well-being of individuals.

Hoffman (1967) listed the following for this species over the whole of its range: Protozoa (1), Trematoda (7), Cestoda (4), Nematoda (2), Acanthocephala (2), leeches (1).

The grass pickerel is known to hybridize in nature with the northern pike (infertile) and to intergrade with the redfin pickerel (fertile).

Relation to man This species, although abundant in certain localities (as high as 111 per acre in Ohio), is not often seen by man. Its small size and the nature of its habitat preclude it from becoming a sport fish in Canada. When seen, they are usually mistaken for the young of the northern pike and they are rarely, if ever, retained or eaten. They will take baited hooks and could provide enjoyable sport on very light tackle.

They are easily maintained in aquaria and make handsome aquarium fishes but usually require live fishes or crayfish as food.

Nomenclature

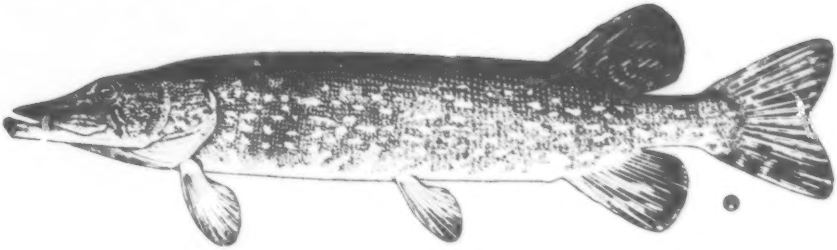
Esox vermiculatus — LeSueur 1846 (*in* Cuvier and Valenciennes): 333 (type locality tributaries of the Wabash River near New Harmony, Ind.)
Esox umbrosus — Kirtland 1854b: 79
Lucius vermiculatus — Dymond 1922: 68
Esox americanus umbrosus — Weed 1927: 23
Esox americanus vermiculatus — Legendre 1952: V

Etymology *Esox* — an old European name for the pike; *vermiculatus* — vermiculated alluding to the wavy bars of the colour pattern.

Common names Grass pickerel, western grass pickerel, mud pickerel, little pickerel, pickerel, central redfin pickerel, grass pike, mud pike. (*See* Weed 1927: 42–43 for list.) French common name: *brochet vermiculé*.

NORTHERN PIKE

Esox lucius Linnaeus



Description Body very long, laterally compressed, only moderately deep, greatest body depth between paired fins 11.0–16.7% of total length, adults not so deep bodied as muskellunge, body cross section a deep oval, more or less flat on top behind head; caudal peduncle moderately long, 10.1–15.0% of total length, but not deep, 4.5–6.0% of total length; individuals are usually 18–30 inches (457–762 mm) in length. Head long, 25.2–30.4% of total length, flat and naked on top, very broad, interorbital width 18.6–25.1% of head length, cheeks usually fully scaled, operculum usually scaled on top half only but variable; eyes large, high and at centre of head, eye diameter 10.7–20.6% of head length; snout long, 42.5–46.8% of head length, but longer than postorbital head length, snout moderately broad and rounded on top; mouth large, horizontal, maxillary usually reaching at least to midpupil; short, sharp, recurved, cardiform teeth along the premaxillary and in patches on tongue, basibranchials, last two pharyngobranchials, vomer, and palatines, large, strong canines on head of vomer, inner edge of palatine tooth patches and on dentaries, those on dentaries flattened with sharp edges as well as points, other canines pointed but round and peglike; lower jaw often extends slightly beyond snout, undersurface of lower jaw usually pierced by 5 pores on each side (rarely 3, 4, or 6 on one side only). Gill rakers reduced to patches of sharp, radiating denticles on one or both sides of the arches. Branchiostegal rays usually 14 or 15 on each side, usually 7 on ceratohyal and 8 on epihyal. Fins: dorsal 1, soft rayed, far back, nape to dorsal origin 38.1–46.0% of total length, base shorter than height and about equal to snout length, upper edge rounded, 15–19 principal rays; caudal long, moderately forked, tips more rounded than the muskellunge; anal origin slightly behind that of dorsal fin, length of base less than height, less than base of dorsal fin, tip rounded, 12–15 principal rays; pelvics abdominal, low, and at middle of body, long, tips rounded and paddle-like, 10 or 11 rays; pectorals low, arising under edge of opercular flap, rounded and paddle-like, 14–17 rays. Scales cycloid and moderately small, 105–148 in the lateral series; lateral line complete, more or less straight, lateral line scales notched not tubed or pierced, very few notched scales elsewhere although golden fleck on exposed edge of most scales make them appear so; intestine long and undifferentiated, no pyloric caeca. Physostomous. Vertebrae 57–65.

Colour The basic colour arrangement of the northern pike is a pattern of light spots on a dark ground coat in contrast to the muskellunge, which is a pattern of dark markings on a lighter background. The dorsal surface, upper sides, and the top and upper parts of the head are dark, brilliant green through olive-green, to almost brown. The ground colour of the flanks is lighter, and in pike over 15 inches (381 mm) long, conspicuously marked with 7–9 irregular, longitudinal rows of yellow to whitish, bean-shaped spots, some as long as the eye diameter. The body has the appearance of being flecked with gold, which results from a tiny gold spot on the tip of the exposed edge of most body scales. The ventral surface of body and head is cream to milk white with fingers projecting up into the ground coat of the flanks. These fingers are all that remain of the characteristic juvenile pattern of this species, long, wavy, white to yellow, vertical bars extending almost to the lateral line. It is these vertical bars that break up into the rows of spots in the adult pattern. Because of the distinctly different pattern, juvenile northern pike are often thought to be a different species and called grass pike. This leads to confusion with the smaller species, the grass pickerel.

The sides of the head are vermiculated with bright golden marks, the eye bars are inconspicuous. The eyes are a bright yellow. The dorsal, caudal, and anal fins are green to yellow or sometimes orange or pale red, blotched with large irregular black markings. The paired fins are usually unmarked and buff to dusky.

Juveniles have similar ground colour but the white of the ventral surface is carried dorsally in 8–12 irregular vertical bars. A mid-dorsal gold to green stripe and subocular bar present as in other esocids but less obvious.

Systematic notes The pike of Europe and of North America were long thought distinct. This concept resulted in many North American synonyms. The variability between eastern North America and western Europe is understandable when one considers its total distribution and the history of its dispersal. Northern pike in North America exhibit two morphological forms (Morrow 1964; McPhail and Lindsey 1970) probably resulting from postglacial expansion from both the Mississippi and Yukon–Alaska glacial refugia.

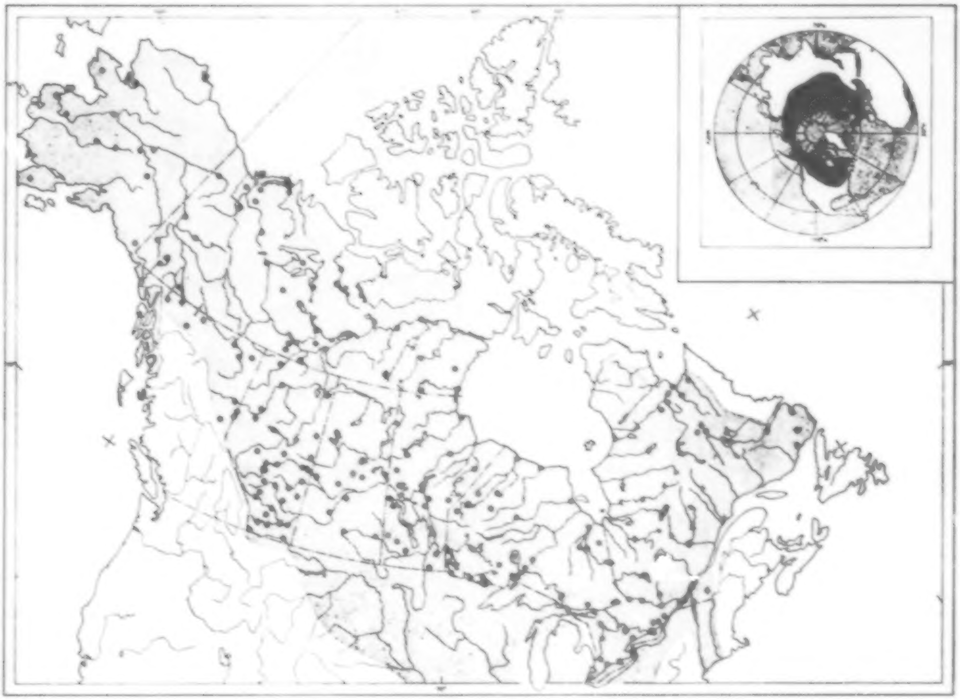
There was considerable confusion in the identity of the northern pike and the muskellunge in North America in the 1800's, and it is only with extreme care that one is able to determine which species was intended when such names as *Esox estor*, *E. nobilior* (and *E. nobilis*), and *E. lucioides* were used.

Distribution The northern pike has a circumpolar distribution in the northern hemisphere. It is primarily a freshwater fish but penetrates very weak brackish water in the Baltic Sea and elsewhere. It occurs in North America from Alaska south to Missouri and Nebraska east of the Rocky Mountains and west of the Appalachian Mountains. It occurs in Lake Champlain and the Hudson River and penetrates south, east of the Appalachian Mountains in the Connecticut River (introduced) in Vermont, New Hampshire, and central Massachusetts. It occurs generally in the United Kingdom and Ireland, all of Europe south to northern Italy, around the Dead and Caspian seas, northeast into Siberia, through the levels of lakes Balkhash and Baikal, and east to the Chukchi Penninsula. Absent from areas of northern and Arctic coastal plains in the USSR, Scandinavia, Canada, and Alaska. Replaced in certain watersheds in eastern North America by the muskellunge and in the Amur River, Siberia, by the Amur pike, *Esox reicherti*.

In Canada, it occurs from Labrador south of Ungava Bay, absent from the Maritime Provinces, present throughout Quebec, upstream in the St. Lawrence from the Nicolet River, throughout Ontario, Manitoba, Saskatchewan, and Alberta, in British Columbia restricted to the extreme northeastern corner, throughout the Yukon and Northwest Territories except for the northern and eastern coastal areas and the arctic islands. *See* McPhail and Lindsey (1970) for details of the distribution in northwestern Canada. It is one of the few species that can be said truthfully to occur throughout Canada.

It has been widely introduced outside its native range in North America to provide a large sport fish and as a control predator.

Biology The northern pike is a spring spawner and spawning takes place immediately after ice melts in April to early May, when water temperatures are 40°–52° F



(4.4°–11.1° C). The 1970 spawning run in Sibley Park (Lake Simcoe), Ont., began on April 11 with a single female, rose rapidly to a peak in numbers of fish by April 18, declined rapidly and ended by April 20. Mean water temperature over that period was 48.2° F (9° C). In general, this species spawns during daylight hours on the heavily vegetated floodplains of rivers, marshes, and bays of larger lakes. A spawning run of 6000 mature pike was tabulated in a single creek tributary to Waskesiu Lake, Sask. (Schultz 1955). The sexes pair at spawning time and a larger female is usually attended by one or

		Age (*years*)						
	TL	1	2	3	4	5	6	7
Georgian Bay, Ont.	*inches*	10.0–21.5	12.0–29.5	18.0–31.0	19.0–35.0	20.5–37.0	25.5–41.0	27.5–41.0
(Wainio 1966)	*mm*	245–546	305–749	457–787	483–890	521–941	648–1041	698–1041
	Wt (*lb*)	–	1.0–7.5	1.5–8.5	2.0–8.0	2.5–12.0	3.5–16.0	4.5–16.5
Waskesiu L., Sask.	*inches*	5.5–7.1	8.0–11.4	13.4–15.0	15.9–18.1	17.7–21.2	18.1–21.4	19.9–23.4
(Rawson 1932)	*mm*	140–180	205–290	340–380	405–460	450–540	460–545	505–595
	Wt (*lb*)	–	–	–	1.5	2.5	–	3.2
L. Athabasca, Sask. and Alta.	*inches*	3.6–5.0	5.2–7.8	7.1–11.2	9.9–13.6	11.4–15.3	13.7–18.9	15.7–20.4
(Miller and	*mm*	92–128	132–198	180–286	253–346	290–390	350–480	400–520
Kennedy 1948b)	Wt (*lb*)	.08	0.12	0.18	0.5	0.6	1.1	1.3
Great Bear L., N.W.T.	*inches*	3.3–4.3	4.6–6.9	6.5–10.4	9.1–13.1	11.8–16.2	13.4–18.5	15.7–20.9
(Miller and	*mm*	85–109	117–175	165–264	232–334	300–411	340–470	400–532
Kennedy 1948b)	Wt (*lb*)	0.1	0.3	0.4	0.6	1.0	1.4	2.0

two smaller males. They swim through and over the vegetation in water often no deeper than 7 inches (178 mm). At irregular intervals the male and female roll, approximate the vents, and eggs and milt are extruded simultaneously during rapid vibration of the bodies. Each spawning act is usually followed by a thrust of the tails, which moves the fish on and scatters the settling eggs. The act is repeated many times during the day for 2–5 days. No nest is built; the eggs are scattered at random, usually in numbers of 5–60 at each spawning act. The eggs, which are 2.5–3 mm in diameter, are clear, amber in colour, demersal, very adhesive, and remain attached to the vegetation of the spawning area. Egg numbers as high as 595,000 have been reported, egg number increases with size of female and has been estimated as 9000/pound female, with 32,000 eggs the average number for mature females. The number of eggs deposited is high, and egg fertility rate in nature is usually over 50%; the number of young resulting from them is very low. In one habitat in Michigan, this was estimated at 1800 young leaving the spawning grounds per million eggs laid, or 99.8% mortality.

Eggs usually hatch in 12–14 days at prevailing water temperatures but can hatch in 4–5 days at 64°–68° F (17.8°–20° C). At hatching, the young are 6–8 mm in length. They remain inactive, often attached to vegetation by means of adhesive glands on the head, for 6–10 days, and feed on the stored yolk. For details of eggs and early development of young, including drawing, *see* Fish (1932). Growth is very rapid, by the end of a month they are 1¾ inches (43 mm) in length and 6 inches (152 mm) by the end of the first summer. Growth in length continues rapidly during the first 1–3 years. Growth in length slows after sexual maturity is attained, but increase in weight rises. Growth is extremely variable from place to place over the extensive Canadian range depending on length of growing season, water temperature, and availability of food (*see* table pages 358 and 359). Many recent studies of growth and age determination by scales demonstrated that age interpretation is made very difficult as a result of local conditions, rate of growth, circuli number and presence of several types of false annuli (*see* Williams 1955; Wainio 1966; Casselman 1967).

Opercular bones and possibly other cranial investing bones may give more reliable results. Published figures on age–length and age–weight relations for several Canadian habitats are below.

There is a decrease in growth rate northward and a corresponding increase in longevity. Females grow faster than males in the south but this trait is not as apparent in the north. However, females over the whole range live longer and achieve a greater maximum size than males. There is a corresponding northward and sexual difference in age at attainment of sexual maturity. In the south of Canada, females mature at 3–4 and males at 2–3 years of age whereas in the north it is

Age (*years*)									
8	9	10	11	12	13	14	15	20	24
29.5–41.0	–	38.8–42.5	–	–	–	–	–	–	–
749–1041	–	990–1080	–	–	–	–	–	–	–
11.0–14.5	–	–	–	–	–	–	–	–	–
21.6–26.3	24.8–27.5	26.3–29.9	27.9–31.4	29.5–32.6	31.8–35.8	–	36.9–37.7	–	–
550–670	630–700	670–760	710–800	750–830	810–910	–	940–960	–	–
–	–	6.5	–	–	12.0	–	17.0	–	–
17.7–23.2	18.5–25.6	20.4–27.9	22.8–28.3	25.2–31.8	26.7–33.8	28.3–35.4	30.3–36.5	40.4–40.9	45.9
450–590	470–650	520–710	580–720	640–810	630–860	720–900	770–930	1020–1050	1160
2.3	3.2	4.0	5.2	6.3	7.6	8.7	9.6	21.0	31.2
18.9–24.0	21.6–26.3	23.6–29.1	25.2–29.9	27.1–30.1	29.5–31.0	30.7–32.6	31.8–34.2	–	–
480–610	550–670	600–740	640–760	690–765	750–790	780–830	810–870	–	–
2.8	3.7	4.5	5.6	6.8	7.3	9.0	10.0	–	–

age 6 for females and age 5 for males. Life expectancy in fast-growing southern Canadian populations can be as low as 10–12 years and in slow-growing arctic populations as high as 24–26 years.

The angler record for northern pike in North America is one of 46 pounds 2 ounces weight and 52½ inches (133.3 cm) length, which was caught in Scanandaga Reservoir, N.Y., in September 1940. In notes of the late J. R. Dymond, written in the 1940's, there was a comment that "Dr. R. B. Miller said he had an authentic record of a 55 pound pike from an Alberta lake." Keleher (1961) reported the largest Canadian pike as 49 pounds, taken from Lake Tschotogama, Que., in 1890. The angler record for Canada is often cited as one caught in Stoney Rapids, Sask., in 1954, which weighed 42 pounds 12 ounces.

Pike are considered to grow much larger in Europe than in North America. European stories of ancient pike and of individuals over 100 pounds are largely fanciful and in the same category as stories of pike that pulled mules and milk maids into ponds. The most legendary is the Mannheim Hoax or Emperor's Pike. This story first related by Gesner in 1558, told of a pike 19 feet (579.5 cm) long, weighing 550 pounds, which was caught in a lake at Württemberg in 1497. This monster was said to have an engraved copper ring *around the gill region* that told of its release there 267 years earlier by Emperor Friederick II. The skeleton, preserved in the Cathedral at Mannheim, was found to contain vertebrae of several individuals. Because of the difficulty of authenticating records of large pike, the world record is contested by the following: a pike that weighed 53 pounds, was 51 inches (129.5 cm) in length and 36 inches (915 mm) in girth, caught in Lough Conn, Ireland, in 1920; a reportedly authentic, Scandinavian pike of 57.2 pounds caught in 1892, and the 74.8-pound pike reported by Berg (1948). Berg also recorded the maximum weight of this species as 143 pounds. This is doubtless an uncritical quotation of some of the fanciful individuals in the European literature. Buller's (1971) list of large British pike included at least eight individuals that equal or exceed the North American record.

In Canada, the habitat of the pike is usually clear, warm, slow, meandering, heavily vegetated rivers or warm, weedy bays of lakes. They do, however, occur in a wide range of habitat over the whole of their extensive distribution. They generally occur in shallower water in spring and fall but move to deeper cooler water at the height of summer temperatures. The young remain in the shallow spawning areas for several weeks after hatching. Some published reports have related to extensive movement of pike in spring (spawning migration) and fall. In general, northern pike are fairly sedentary, establishing a vague territory where cover and food are adequate. Most often, northern pike, especially the young, are taken in the top 15 feet of water. They have been taken in Lake Nipigon, Ont., in late summer from depths over 100 feet. They are active and feed (to a lesser degree) in winter and are an important ice fishing quarry. They occur in alkaline lakes with total alkalinities as high as 1000 ppm and pH as high as 9.5 in Nebraska, and salinities as high as 1.6% in Saskatchewan. High alkalinity can reduce or prevent spawning and has a greater effect on the young than on adults. The northern pike is usually classified as a primary freshwater species but salinities of 18‰ will kill it. It is known to occur in salinities as high as 10‰ in the Baltic Sea and to be able to reproduce in salinities as high as 7‰.

After the yolk is absorbed, young pike feed heavily on larger zooplankton and some immature aquatic insects, for 7–10 days. At this point, small fish enter the diet and by the time the young reach 2 inches (50 mm), fish assume predominance. Adult pike can be classed best simply as omnivorous carnivores in that they eat virtually any living vertebrate available to them within the size range they can engulf. The optimum food size has been calculated at between one-third and one-half the size of the pike. Food selection by species is not apparent and the direct relation between size of food item and size of northern pike is apparently not so pronounced as in the case of the muskellunge. The northern pike would seem to be an opportunist and to feed on whatever is most readily available. Whereas the food of adults over the whole season is over 90% fish, adults do at times feed heavily on frogs and crayfish. Other vertebrates such as mice, muskrats, and ducklings often enter the diet. Lawler (1965b) gave a complete analysis of the food of this species in Heming Lake, Man. The amount of food consumed seems staggering. Toner (1959) estimated that 2594 pike ate, in one year, 112.5 tons of brown trout as well as a smaller amount of perch. Lagler (1956) estimated that an average of 1.5 million water fowl were eaten by northern pike on a single wildlife refuge in Michigan although fish were the main item of food. It has been estimated that it takes 5–6 pounds of food for each pound increase in body weight of a northern pike. This figure and the potential maximum weight indicates the effect by predation of this species on the other vertebrates in its habitat.

Earlier spawning, faster growth, early dominance of fish in its food, and better food conversion are cited as the contributing factors in the success of the northern pike over the muskellunge when they occur together. Young and older pike consume the young muskellunge, and the pike at all ages is a direct and more successful competitor of the muskellunge for space, food, and spawning sites. It is also a predator on, or a competitor for food with, many other predaceous, sometimes economically more important, fishes such as the basses (*Micropterus* spp.) and walleyes (*Stizostedion* spp.).

The eggs and young of the northern pike are prey to a wide variety of other fishes, including northern pike, minnows, and perches; of the large larvae of various aquatic insects; of waterfowl and other diving birds, and of aquatic mammals. Mortalities on the spawning grounds of eggs and young by predation, or by stranding due to lowering water levels, have been estimated as high as 99%. Adult pike are large enough and secretive enough that lampreys and man are probably their only important enemies. During spawning when the adults are in very shallow water and are unwary, the smaller ones are taken by bears, dogs, eagles, and ospreys.

The northern pike is host to a vast assemblage of parasites. Toner (1966) in his summary of information on the pike listed almost a full page of published records. Hoffman (1967) listed the following parasites for this species in North America: fungi (1), Protozoa (19), Trematoda (48), Cestoda (13), Nematoda (23), Acanthocephala (18), leeches (4), Mollusca (2), Crustacea (10). (*See also* Hunter and Rankin 1939.)

The parasite most often seen and of concern to anglers is the strigeid fluke *Uvulifer ambloplitis*. The externally encysted stage of this trematode, called black-spot (Crossman 1962d), is often present in extreme numbers on individual pike. This parasite is not transferrable to man, is readily killed by adequate cooking or removed by skinning rather than scaling the fish.

This species also suffers from a septicaemic "red sore" disease caused by the bacterium *Pseudomonas hydrophila*, which is also responsible for the condition in frogs known as "red leg." In northern pike it results in ugly red necrotic lesions involving the muscle tissue (Margolis 1951). The pike also are subject to neoplastic tumors that are true cancerous lymphosarcoma. Both render the fish very unsightly and cause great concern to those who catch infected fish. Neither of these "diseases" is known to be transferrable by contact to man. Infected fish should not, however, be returned to the water. Two tapeworm parasites, *Diphyllobothrium latum* and *Triaenophorus crassus* have a direct and indirect effect on man (*see Relation to man* section).

In various parts of North America, the northern pike hybridizes with the muskellunge, the chain pickerel, the redfin pickerel, and the grass pickerel. If there is any fertility in such hybrids it is only in the females. The northern pike × muskellunge hybrid, now known as tiger muskellunge, is said to demonstrate hybrid vigor in growth, body proportions, and activity. For these reasons it is a better sport fish and is now cultured and released for this purpose.

A mutant form of the northern pike, now called silver pike, first reported by Prince

(1898) from the area near Sharbot Lake, Ont., is now known to occur sporadically throughout the world distribution of the northern pike. It is unique in that it has none of the white to yellow spots characteristic of this species, the ground colour is metallic blue, metallic green, or bright silver. It is otherwise indistinguishable from the northern pike except in apparent increased hardiness (*see* Lawler 1960).

Relation to man Few fishes enjoy as ambiguous a relation to man as does the northern pike. In most areas of Canada, it is both a commercial fish and a sport fish and consequently not protected by game laws. In some areas, it is looked upon as a nuisance and a destroyer of more important species, whereas in others it is one of the sport fishes that annually attract large numbers of anglers and dollars. It is a delicious food; the flesh is sweet, white, and flaky. If properly prepared, best after skinning, there is rarely any so-called muddy flavour often attributed to it in summer. This unwanted characteristic may result from the heavy pigment and mucus of the skin if the fish is prepared for cooking by superficial and hurried scaling. The northern pike is also the host of two troublesome parasites. The broad fish tapeworm *Diphyllobothrium latum* in certain areas infects this species and if the flesh of the fish is inadequately cooked, then eaten, this parasite can be transferred to man (*see* Roussow 1960). Another parasite, the cestode *Triaenophorus crassus*, for which the northern pike is the final host, encysts at an earlier stage in the musculature of the lake whitefish rendering the flesh of that species unacceptable by law for human consumption. Annually, thousands of pounds of whitefish, most often after capture and processing, must be discarded as a result of this parasite (*see* lake whitefish; Lawler and Scott 1954).

The northern pike has always been an important commercial fish but a small percentage of the total commercial catch. As is the case with most Canadian fishery products, often as much as 80% of the annual Canadian landings are exported to the United States. The marketed catch in the years 1913–24 fluctuated between 3.7 and 7.7 million pounds with an average of 5.58 million pounds. The annual commercial catch in the United States at this time ranged between 3.22 and 6.06 hundred thousand pounds.

The price to the fisherman in 1924 fluctuated between 3.6 and 5.8¢/pound. In 1967 the commercial catch in Canada was approximately 7.4 million pounds with a landed value of $481,000, which represents 15.5¢/pound.

In 1966 the total commercial catch of this species in Ontario alone was just over one million pounds with a market value of $84,962.05. It ranks fourth by weight (after whitefish, lake trout, and walleye) in the list of commercial species taken in Saskatchewan where approximately 1 million pounds are marketed annually; 2–3 million pounds are harvested annually in Manitoba. They are part of the summer commercial catch in most areas and in the northwest they are taken by gillnets under the ice in winter. Northern pike are usually sold commercially fresh, either live, in the round, or headed and gutted, rather than as fillets.

Standing crop of pike in various habitats across North America probably ranges from 8 to 25 pounds per acre. The maximum standing crop is that of 50.3 pounds per acre reported from an unexploited, newly flooded impoundment in Iowa (Threinen et al. 1966).

As a sport fish, the northern pike can provide considerable enjoyment. It is usually taken by trolling with large spoons, plugs, bucktail spinners, large bait fishes, or worm harness. Casting the same types of lures into or near weed beds yields good results and still fishing in deeper water off the edge of weed beds is usually best in the middle of summer. Angler success is usually rated at 1.8–2.2 fish/hour in good areas. The usual size caught by anglers is 18–22 inches, but in northern Canada numbers of northern pike up to 42 pounds are caught annually. In some northern areas, catches of 10–20 fish weighing in the aggregate over 200 pounds can easily be taken in a few hours. Unlike the muskellunge, hooked pike fight in the depths rather than by jumping out of the water. They are an important sportfish in the winter fishery through the ice as well. They are caught ice fishing with live or salted baitfish or by jiggling artificial lures.

Pike are also used as a farm pond species in warmer water, often in combination with bluegills. They are looked upon as good natural control of the numbers of smaller species to prevent overpopulation and stunting. They are propagated and reared in enclosed areas for food in Europe.

Nomenclature

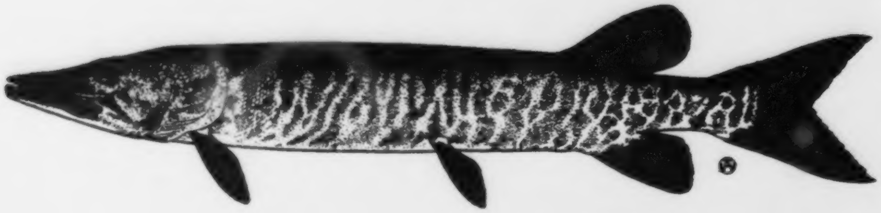
Esox Lucius — Linnaeus 1758: 313 (type locality Europe)
Esox estor — LeSueur 1818b: 413
Esox Lucius — Richardson 1823: 716
Esox lucius (Linn.) — Richardson 1836: 124
Esox Boreus — Aggasiz 1850: 317
Esox lucioides — Aggasiz and Girard 1850: *in* Herbert (1850): 154
Esox lucius var. *estor* — Jordan 1876: 255
Lucius lucius — Jordan and Evermann 1896–1900: 628

Etymology *Esox* — an old name for the pike in Europe; *lucius* — the supposed latin name for this species.

Common names Northern pike, pike, great northern pike, jack, jackfish, pickerel, great northern pickerel. *See* Weed (1927), and Buss (1961) for lists of regional common names. French common names: *brochet, grand brochet.*

MUSKELLUNGE

Esox masquinongy Mitchill



Description Next to sturgeons this is Canada's largest freshwater fish. Previously known to exceed 6 feet (183 cm) in length and 100 pounds in weight, muskellunge are now most often seen in the length range of 28–48 inches (711–1220 mm) and weights of 5–36 pounds. Body long, moderately laterally compressed, moderately deep and wide in large adults, greatest depth 10.3–16.3% of total length (young-of-the-year are longer and more slender), cross section a long oval, flat on top ahead of dorsal fin; caudal peduncle fairly deep for length, depth 4.6–7.1% of total length. Head long, 23–25% of total length, massive in large individuals and wide, interorbital width 18.1–23.7% of head length, flat to concave and naked on top; cheeks and opercles usually scaled only on upper half but variable; eyes high, large, 9.7–13.1% of head length, at centre of head; snout long, 42.9–47.2% of head length, broad, appears longer and narrower in first 2 or 3 years; mouth horizontal, large, maxillary extending to midpoint or posterior edge of pupil; short, sharp, recurved cardiform teeth along the premaxillary and in patches on tongue, basibranchials, last two pharyngobranchials, vomer, and palatines, large, strong canines on head of vomer, inner edge of palatine tooth patches, and dentaries, those on dentaries flattened with sharp edges as well as tips, other canines pointed, but round and peglike; lower jaw often slightly longer than snout, undersurface of lower jaw pierced by 6–9 pores on each side (rarely 5 or 10 on one side only). Gill rakers reduced to patches of sharp, radiating denticles on one or both sides of arches. Branchiostegal rays 16–19 on each side, usually 8 on the ceratohyal and 10 on the epihyal. Fins: dorsal 1, soft rayed, far back, nape to dorsal origin 40.6–50.6% of total length, base shorter than height of fin, fin height slightly greater than snout length, tip rounded, 15–19 principal rays; caudal long, deeply forked, tips pointed; anal origin slightly behind origin of dorsal, near anus, base and height less than those of dorsal fin, edge less rounded, principal rays 14–16; pelvics abdominal, at midpoint of body, low, pointed, 11 or 12 rays; pectorals low, arising under edge of opercular flap, rounded, paddle-like, 14–19 rays. Scales rather small, cycloid, 132–167 in the lateral series; lateral line present, complete, lateral line scales notched not pored or tubed, few if any notched scales elsewhere; intestine long, undifferentiated, no pyloric caeca. Physostomous. Vertebrae 64–66.

Colour The overall colour scheme in the muskellunge can be generally characterized as extremely variable, but with consistent dark markings on a light background, in contrast to the northern pike, which has light markings on a dark background. There is considerable variability between individuals in the same area, and between areas, in ground colour and in the nature of the dark markings.

In adult muskellunge the back, head, and upper sides are iridescent green-gold to light brown, the flanks range from green, through green-gold to brownish, to grey or very silvery. Often in very silvery specimens, no dark markings, or only vague suggestions of dark markings, are visible. In the others the brown to black markings of the flanks take the form of spots, prominent vertical bars, blotches, vermiculations, or combinations of two or more of these.

All dark patterns are represented with different frequencies in all areas. The only distinctions that can be made are that muskellunge in the St. Lawrence River–Great Lakes exhibit the spotted pattern with far greater frequency than those in the other areas; and there is a slight tendency for western fish to be clear of markings. This latter tendency is greater everywhere in the largest specimens, a silvery overlay hides the pattern. The pattern, however, is present and is more obvious after death or preservation. *See* Hourston's (1955) complete analysis of the relative occurrence of pattern types in three Canadian areas and the difficulty of assigning any pattern to any area.

The ventral surface is cream coloured to milk-white with small brown to grey spots or blotches. The head, dark above, paler on the sides, is marked with spots or by several dark bars radiating from the eyes. The fins are greenish or buff to red-brown, with dark blotches, blotches more prominent on unpaired than on paired fins. Unpaired fins are often bloodred on capture from nets or angling as they apparently hemorrhage very easily during the vigorous activity associated with boating a large individual.

Young-of-the-year, less than 6 inches (152 mm) in length, which are pencil shaped, are distinctively marked on the sides with scalloped black to blue-green on back, head, and upper sides, and white to buff below. They also have the characteristic gold to gold-green mid-dorsal stripe so characteristic of the young of this family.

Systematic notes The muskellunge exists in semidiscrete populations: (1) St. Lawrence River–Great Lakes and tributaries; (2) Ohio River and tributaries; (3) Wisconsin, Minnesota, northwestern Ontario, and southeastern Manitoba. As a result of supposed morphological differences and supposed distinct patterns, muskellunge in these areas were originally described and considered as distinct species and later considered subspecifically distinct: (1) *E. m. masquinongy* — spotted; (2) *E. m. ohioensis* — barred or diffuse spots and blotches; and (3) *E. m. immaculatus* — no pattern or barred. A study published by Hourston (1955), which did not include the Ohio River form, suggested differences in the populations in the St. Lawrence and in western Ontario but emphasized the difficulty in recognizing subspecies in the muskellunge. The tendency since that time has been to treat it as a single variable species.

The situation is greatly clouded now as a result of fish cultural activities and extensive plantings. The Ohio River type has been liberated in Lake Erie and in Quebec.

The literature on this species in the late 1800's is a morass of confusion. The muskellunge was poorly known; descriptions were fragmentary; the muskellunge was repeatedly confused with, and scientific and common names interchanged with, the northern pike; and figure captions were repeatedly reversed. It is only with great care that one is able to sort out what was intended by various early authors when they used such names as *Esox estor*, *Esox nobilior* (or *nobilis*), and *Esox lucioides*.

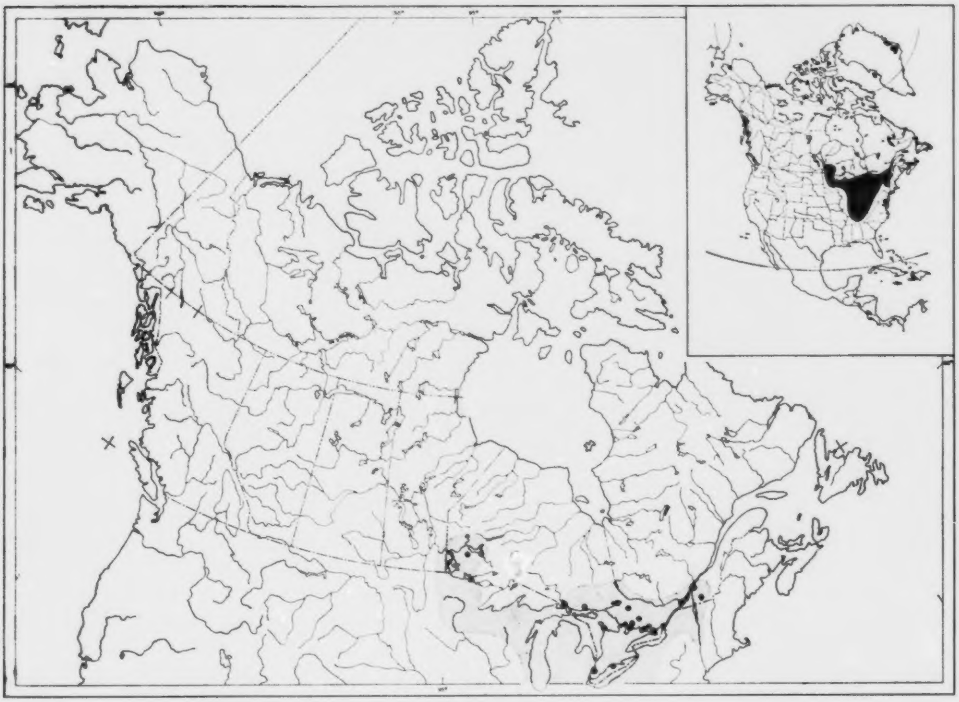
Another name, *Esox amentus*, was introduced in the sporting literature (Godfrey 1945) as that of the True Tiger Muskellunge from lakes in the Sioux Lookout area of northwestern Ontario. The fish in question was a northern pike × muskellunge hybrid with the characteristics and pronounced bars of that combination. The true muskellunge in Minnesota had long been called tiger musky. As a result of Godfrey's popular account, a study was carried out and Cameron (1948) described and documented the hybrid from the Sioux Lookout locality. Bishop (1946) commented on the introduction of the name into the literature.

Distribution This species is restricted to the fresh waters of eastern North America. Its range extends south from Quebec, through western Vermont, south, west of the mountains to Tennessee; north, avoiding the main stem of the Mississippi, through eastern Illinois (rare) into Wisconsin, Minnesota, western Ontario, and extreme southeastern Manitoba. Liberated elsewhere to the south and west in the United States but not always successful.

In Canada the muskellunge occurs in lakes and rivers from southern Quebec, the St. Lawrence and its north and south tributaries from the area of Trois Rivières (Rivière Bécancour) upstream; the Ottawa River and some of its tributaries north to about the level of Lake Nipissing; throughout the lower Great Lakes and parts of such tributary systems as the Trent and Severn rivers; north, including Lake Nipissing to near Sault Ste. Marie. Absent from the north shore of Lake Superior (present in some south shore tributaries) and from the area west to Rainy Lake. Present but less abundant in the area from Rainy Lake to Lake of the Woods; more abundant in Lake of the Woods and the English River, north to the Sioux Lookout area. It has been introduced in eastern Manitoba and has recently spread naturally into that province.

Older records (Radforth 1944) for the north shore of Lake Superior near Schreiber, and north in the Ottawa River to Lake Abitibi were probably based on sporting magazines and unauthenticated replies to a questionnaire.

Biology The muskellunge is a spring spawner. Unlike the smaller members of the family there has been no report of its spawning in the fall. It spawns shortly after the ice has melted (but later than the northern pike) usually in late April or early May when the water temperature is 49°–59° F



(9.4°–15° C), but optimum temperature is 55° F (12.8° C). Spawning takes place in water 15–20 inches deep in heavily vegetated flooded areas. During the spawning period the fish pair off, usually a larger female is accompanied by one, or at times two, smaller males. They swim about over the vegetation during the day, and at intervals the fish roll so that the anus of male and female are approximated; a small number of eggs and sperm are shed simultaneously during rapid vibration of the bodies; the lashing of the tails spreads the fertilized eggs and the pair swim on. The spawning act is carried out many times at irregular intervals over several days. No nest is built, the semidemersal, apparently nonadhesive eggs, are scattered at random and drop into the vegetation. Spawning usually lasts no more than a week. The number of eggs increases with size of the female and ranges from about 6000 to 265,000 with the usual number about 120,000. Fertilized eggs are 2.5–3.5 mm in diameter, clear, and amber coloured. Hatching occurs in 8–14 days at water temperatures of 53°–63° F (11.7°–17.2° C). Often only 34% of the eggs spawned naturally are fertile whereas fertility of eggs reared in a hatchery is often as high as 95%.

On hatching, the young are 9.5–10.3 mm in length and may, in nature, remain dormant in the vegetation for about 10 days or until the yolk is consumed, at which time they become active and begin feeding. For details of egg and early development of the Ohio River type (Chautauqua Lake) including drawings, *see* Fish (1932).

Growth in the first season is rapid, by 10 weeks of age muskellunge are approximately 6 inches (152 mm) in length. By November of the first year they are 10–12 inches (254–305 mm) in length. Growth is rapid in the first few years also. Rate of increase in length slows as sexual maturity is achieved, but rate of increase in weight continues virtually into old age. Growth rate varies from locality to locality depending on the availability of food fishes of the appropriate size. Growth rate in various Canadian localities was given by Hourston (1952). Mean fork length at various ages for the St. Lawrence River population was given as follows:

Age (*years*)	Mean FL (*inches*)	Mean FL (*mm*)	Avg wt (*lb*)
2	18.4	476	1.4
3	23.1	587	3.2
4	27.2	692	5.8
5	31.4	798	8.7
6	32.4	824	9.9
7	34.5	876	11.8
8	37.6	956	15.8
9	41.6	1056	21.3
10	44.7	1137	25.3
11	44.3	1125	28.0
12	43.0	1093	24.9

There is striking sexual dimorphism in growth; females grow faster than males, are larger at any age, live longer, and consequently all the notable-sized muskellunge are females. Sexual maturity is reached between 3 and 5 years, with the males maturing at a smaller size but with no apparent difference between the sexes in age at attainment of maturity. Most growth tables are limited by adequate representation to 12–15 years of age, but the record catches are all much older. The present angler record is a muskellunge 64.5 inches (163.8 cm) in length, 31.75 inches (80.6 cm) in girth, which weighed 69 pounds, 15 ounces. This fish was caught in the St. Lawrence River in September 1957. Extrapolating Hourston's (1952) age–length curve yields an estimated age of 22 years. Smaller muskellunge have been aged at 21 years and Oehmcke et al. (1958) referred to age determinations in excess of 30 years. Most fish seen by anglers are in the range of 30–46 inches (76.2–116.8 cm), weigh 8–36 pounds, and are 3–15 years old. The oft-quoted but unauthenticated maximum size is said to be a muskellunge that weighed 102 pounds, netted in the early 1900's in Wisconsin. Carlander (1969) stated that the report of a muskellunge purported to have weighed 109.7 pounds and to have been 88 inches (223.5 cm) in length was a hoax.

The habitat of the muskellunge in Canada is warm, heavily vegetated lakes, stumpy, weedy bays, and slow, heavily vegetated rivers. It is so regularly found among dense growths of one or more of several species of pondweed (*Potamogeton* spp.) that anglers refer to these aquatic plants as "lungeweed". Other than the largest individuals, the muskellunge is rarely found far from the protection of growths of emergent and sub-emergent plants such as water lilies, pickerel weed, arrow leaf, coontail, cattail, and pondweed, or areas of drowned timber and stumps. Water temperature up to 78° F (25.6° C) would appear to be optimal but this species can withstand water temperatures as high as 90° F (32.2° C). They can apparently withstand the low summer oxygen levels of these sluggish, shallow habitats. Very large individuals are often found in or over deeper, less vegetated water and to a depth of 50 feet. Other than at spawning time, muskellunge are solitary, sedentary animals lurking in concealment in the vegetation or near stumps. They move little, other than to dart swiftly after single prey fishes, which they often carry back to the protective area before swallowing.

The young, as soon as they become active, begin feeding voraciously on larger zooplankton, usually cladocerans. This ration continues for 1–3 weeks and the fish then utilize some plankton and some small fishes. Usually after a length of 1.5 inches (38 mm) is attained the diet is fish alone. There appears to be a direct relation between size of muskellunge and the size of food fish selected. Growth and survival of larger muskellunge is often impaired if food of an adequate size is not available, in spite of vast numbers of smaller fishes. A wide variety of warmwater fishes such as perches, suckers, larger minnow species, mooneyes, catfishes, and sunfishes are usually represented in the diet depending on the fauna associated with the muskellunge in any habitat. As with other pikes they seem invariably to strike prey fishes so as to take them sideways in the mouth. They often retreat to protection with the fish so impaled on the large canines. The food item is then rotated and swallowed head first. Since a large part of the food is large spiny-rayed fishes, this habit facilitates the collapse of the spiny rays during the process of engulfing the food. Fishes form by far the largest part of the diet of larger muskellunge but practically any living animal, including crayfish, frogs, muskrats, mice, shrews, and a variety of waterfowl (young and adult) have been recorded from the stomachs of this species. *See* Hourston (1952) for a quantitative and qualitative analysis of food. The supposed voracity of muskellunge, which have been, like northern pike, referred to as water wolves, is legendary.

Many species of fishes prey on the very young, nearly immobile muskellunge and these include northern pike, muskellunge (rarely), yellow perch, basses (*Micropterus* spp.), rock bass, and sunfishes. In hatchery situations, and possibly in nature as well, diving beetles, electric light bugs, and the large larvae of some aquatic insects are significant predators on newly hatched muskellunge. In situations where earlier-hatching northern pike and muskellunge cohabit and utilize the same spawning areas, predation of muskellunge hatchlings by pike fingerlings is considered to be a major reason for the failure of the muskellunge to survive this contact. Larger muskellunge are nearly free of predation except possibly by large birds of prey and bears. The great size of some spawners, the high regard in which the fish is held, the shallow water of spawning sites, and the loss of wariness at spawning time make the muskellunge easy prey to disastrous reduction of numbers by poaching. This is an annual problem in many areas.

The habit of spawning on flood plains may, at times, constitute a serious limiting factor for this species. Even slight decreases in water level in those areas can result in the stranding and death of spawners or young. More drastic changes in level can expose the developing eggs.

The muskellunge and the northern pike often hybridize in nature, producing a shorter, more robust fish with very pronounced barred marking of the muskellunge parent. The males are always sterile but female hybrids are often fertile. This fish is now referred to as the tiger muskellunge, a term previously used for the prominently striped muskellunge characteristic of some areas of Wisconsin and Minnesota. Hybrid vigor in this cross is said to result in a fish of better sporting qualities than the northern pike, but able to live where the muskellunge cannot, and it is being cultured and liberated in the United States. A study of this hybrid in western Ontario was carried out in 1946 (Cameron 1948).

Hoffman (1967) listed the described parasites of the muskellunge as follows: Protozoa (8), Trematoda (9), Cestoda (4), Nematoda (6), Acanthocephala (4), Mollusca (1), Crustacea (4).

Both the muskellunge and the northern pike are subject to lymphosarcoma which, at times, result in large, most unsightly, open, red, cancerous tumors. The role of the tumors in the spread of the condition is not fully known. Care should be taken handling tumorous fishes and they should not be returned to the water.

Relation to man The anticipation of the possibility of capturing a world's record muskellunge (which now would have to exceed 70 pounds) or even a single, legal-size fish (30 inches or 762 mm total length), annually draws thousands of anglers and their families to the known haunts of this species. To a vast and devoted coterie of avid muskellunge anglers, pursuit of Canada's largest true freshwater sport fish provides the peak of aesthetic enjoyment in beautiful outdoor surroundings. To a wide variety of others — guides, boat and motor sales and rental agencies, tourist operators, and merchants — the pursuit of the muskellunge means cash incomes. There has never been an accurate economic appraisal of the muskellunge fishery, but it would be safe to say that it contributes several million dollars annually. It is usually estimated that the capture of a legal muskellunge requires 100 man-hours of angling. The yearly catch in Pigeon Lake (Kawartha Lakes, Ont.) alone was estimated (Spangler 1968) at 895–2505. It has been reported that in 1955, 75,000 pounds of muskellunge were captured by anglers in Ontario alone. These figures readily yield estimates of both the enjoyable, and sometimes frustrating, hours of recreation and the cash benefit derived from the fishery for muskellunge. The good possibility of a 10- to 49-pound catch, the excitement of the strength and the aerial acrobatics of a hooked muskellunge, which may take up to an hour to land, is a thrill no angler forgets. Muskellunge are usually sought by trolling a very large artificial lure (up to 12 inches in length) such as a plug, bucktail spinner or spoon, or a large, live bait fish such as a perch or sucker. The other chief and often more enjoyable means used is casting such artificial lures or live bait in and around the weeds or stumps of a typical muskellunge habitat. The muskellunge moves very little so still fishing is usually of no avail.

Muskellunge were not always exclusively sport fish. The size of the fish and the high quality of its flesh made it very acceptable as a commercial species. Between 1870 and 1900 thousands of pounds were marketed annually in Quebec and Ontario. The Ontario statistics for 1890 listed a commercial catch of 651,406 pounds and noted that most of the catch was from Lake Scugog. A commercial catch record for Lake Simcoe in 1868 listed 229,050 pounds.

Commercial fishing was ended by 1904 in Ontario in the face of drastic increase in angling interest and intensity and decrease in catch. It continued in Quebec at least until 1936 (Dymond 1939). Over the years, legislation gradually added season, size, daily bag, and possession limits until today this species can be taken generally only in July–October, in excess of 30 inches (762 mm) total length and in numbers no greater than two per day per angler. In addition to protective regulations, a hatchery in Quebec and one in Ontario attempt to support the number of muskellunge available to the angler. Eggs and milt are taken from wild fish, the eggs reared in the hatchery, and the young in hatchery ponds. The problems of providing the live fishes required for food by young pond-reared muskellunge — 6 million food fish to produce 8000 muskellunge averaging 9 inches (229 mm) in length — dictate that they be released into natural waters as quickly as possible.

The flesh is highly flavourable, white, and flaky. Larger muskellunge, if not saved for mounting, are usually baked, poached in butter, or steaked and fried, but the smaller ones are said to be more flavourful if fried fish is desired. The best results are achieved if the fish is skinned, for the heavy mucus over the skin probably contributes what some people term a muddy flavour in midsummer.

Nomenclature

Esox masquinongy — Mitchill 1824: 297, *from* DeKay 1842: 222 (type locality Lake Erie)
Esox estor (LeSueur) — Richardson 1836: 127
Esox nobilior — Thompson 1850: 163
Esox nobilis — Kirtland 1854b: 79
Lucius masquinongy (Mitchill) — Jordan and Evermann 1896–1900: 629
Esox immaculatus Garrard — Weed 1927: 30
Esox masquinongy masquinongy Mitchill — Hubbs 1926: 53
Esox amentus — Godfrey 1945: 36

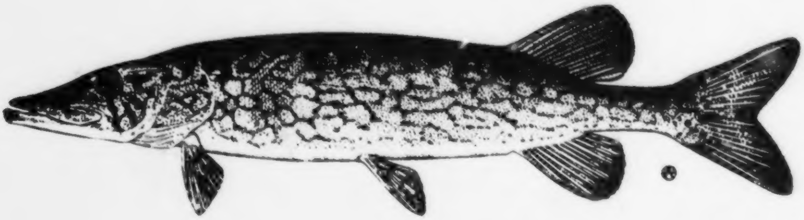
Etymology *Esox* — a European name for the pike; *masquinongy* — variously given as from the Indian through French phonetic spelling. The two most often quoted derivations are mashk — deformed, and kinonjé — a pike; and mis or mas — large, and kenosha — a pike.

Common names Muskellunge, maskinonge, Great Lakes muskellunge, Ohio muskellunge, Wisconsin muskellunge, musky, lunge, tiger muskellunge. French common name: *maskinongé*.

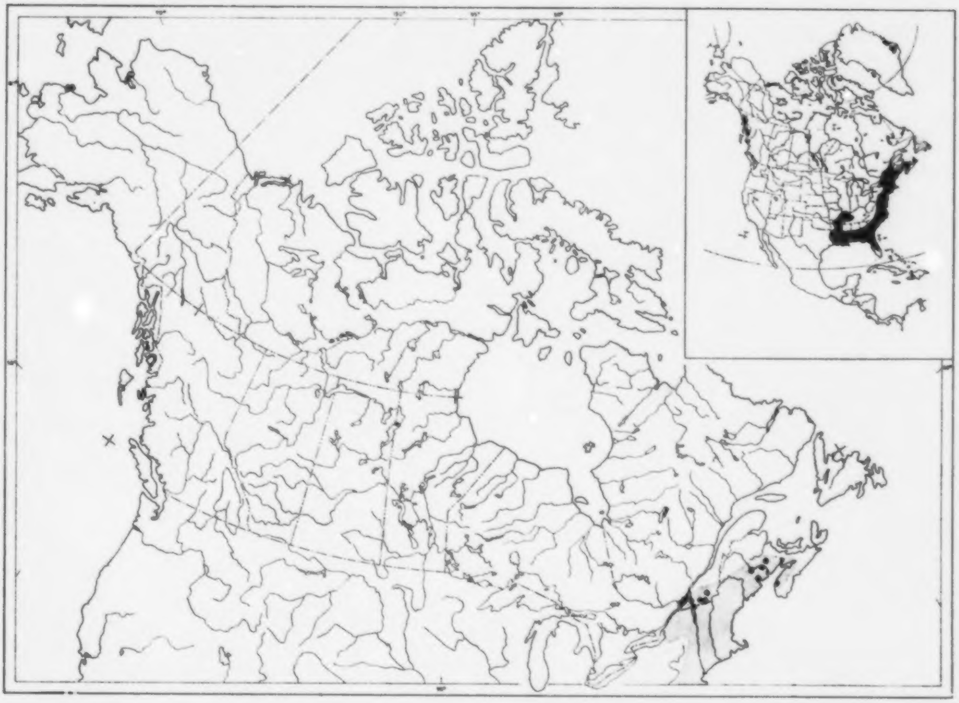
Muskellunge is now the standard common name but maskinonge is a statute name in Ontario and Quebec, in an attempt to retain the French version of the supposed Indian name. Among two pages of common names used in the literature for this species, Weed (1927) gave 41 variations of the "original Indian" name. The name tiger muskellunge was common in Wisconsin and Minnesota but this name has now been more or less transferred to the hybrid northern pike × muskellunge.

CHAIN PICKEREL

Esox niger Lesueur



Description Body long, narrow, moderately compressed, somewhat flat dorsally, shallow, greatest depth between paired fins 11.5–15.5% of total length, cross section a long oval; caudal peduncle moderately long, 13.4–17.8% of total length, and narrow, depth 4.3–5.9% of total length. Individuals usually 15–20 inches (381–508 mm) in total length. Head long, 26.1–28.5% of total length, flat and naked on top, narrow, interorbital width about 20% of head length, somewhat concave between eyes; cheeks and opercula fully scaled; eyes high on head, moderately large, diameter about 14% of head length; snout very long, 44.3–48.0% of head length, rounded and concave, often likened to a duck's bill, narrower than other species; mouth large, maxillary reaching anterior edge of the pupil; short, sharp, recurved cardiform teeth along the premaxillary and in patches on tongue, basibranchials last two pharyngobranchials, vomer, and palatines; large, strong canines on head of vomer, inner edge of palatines, patches and on the dentaries, those on dentaries flattened with sharp edges as well as tips, other canines pointed but round and peglike; lower jaw very slightly longer than snout, undersurface of lower jaw pierced by 4 pores on each side (sometimes 5 on one side only). Gill rakers reduced to patches of sharp, radiating denticles on lateral and medial surfaces of arches. Branchiostegal rays 14–17 on each side, usually 15 (6 on ceratohyal and 9 on epihyal). Fins: dorsal 1, soft rayed, far back, occiput (or nape) to dorsal origin 40.3–44.4% of total length, base short, about 33% of head length, a little less than height, fin moderately high, height about 50% of head length, edge square to slightly rounded, 14 or 15 principal rays; caudal long and deeply forked, tips pointed; anal under dorsal fin, base slightly shorter than dorsal fin, not so high as dorsal fin, slightly shorter than snout, edge more rounded, 11–13 principal rays; pelvics abdominal and low, in advance of vent, narrow, long and with rounded edge, 9 or 10 rays; pectorals with base starting



under edge of opercular flap, low, moderately long, rounded on the edge, and paddle-like, 12–15 rays. Scales rather small, cycloid, long, and narrow, usually 3 lobes on embedded edge, 117–135 in lateral series, usually about 125; lateral line complete, lateral line scales notched not pierced or tubed and single notched scales bordering sensory cells scattered elsewhere on body; intestine long and undifferentiated; no pyloric caeca. Physostomous. Vertebrae 52–54.

Colour Ground colouration of adults bright green, through olive-green to nearly brown on dorsal surface and upper sides, flanks prominently marked by yellow-green to yellow areas broken by dark, interconnecting markings resembling links of a chain (hence common name), scattered tiny gold flecks on exposed edges of some scales; ventral surface creamy white; pronounced, black, horizontal preocular and vertical subocular bars, less obvious in very large individuals. Dorsal and anal fins with dark pigment on rays, contrasting with little to no pigment on membrane, pectoral and pelvic fins much less marked, caudal fin base marbled with dark pigment, tips dusky. Pupil of eye yellow. Young are bright green through brown to almost black on the dorsal surface, with a pronounced golden mid-dorsal stripe. The upper flanks are bright green to almost black. This colour extends in wedges or bars down to the lower flanks, rest of flanks and belly white, fins clear to dusky, chain markings not developed in individuals less than 6–8 inches (152–203 mm) in length.

Distribution Restricted to eastern and south-central North America south from Digby County, N.S., east of the Allegheny–Appalachian mountains, to central Florida, west in the Gulf states to Caddo Lake in eastern Texas and north in the Mississippi River drainage to Missouri and the Tennessee River system in Alabama. Introduced elsewhere in the states west of the mountains such as Colorado, Ohio, Pennsylvania, as well as in the Lake Erie drainage of New York State. Typically a freshwater fish of the coastal Plain (below the fall-line) but known to penetrate brackish water in the eastern and Gulf states.

In Canada it occurs only in Nova Scotia (Digby County only, and introduced there from the United States), western New Brunswick, and the Eastern Townships of Quebec south of the St. Lawrence River, including Lake Champlain. Records in the early 1900's from Toronto Harbour and Kingston are in error. The young of chain pickerel and northern pike bear a superficial resemblance.

Biology Probably as a result of its limited distribution in Canada, and the fact that it is of virtually no commercial importance and is considered of little importance as a sport fish even in those areas where it does occur, there is virtually no published information on Canadian populations of this species. Published information on populations in the New England and other states is more abundant, and the literature has been drawn together in summaries by Wich and Mullan (1958), McCabe (1958), and Carlander (1969). The information below is based, wherever possible, on populations in the northern United States, in environmental conditions similar to those in Canada where this species occurs.

The chain pickerel, like the other esocids, is basically a spring spawner but in the United States some individuals may spawn in the fall (Miller 1962). In the spring, adults enter the spawning areas, flood benches of streams, lakes, or ponds, very shortly after the ice melts. Spawning takes place in water 3–10 feet deep when water temperatures reach 47°–52° F (8.3°–11.1° C) in April or May and probably lasts no more than 7–10 days. No nest is built. A single female, accompanied closely by one or two usually smaller males, swims slowly about in a random way, usually over flooded vegetation. Periodically during the daytime, the female and a male roll inward slightly in a sharp body flexure so that the vents approximate, eggs and milt are shed simultaneously and a violent lash of the tails spreads the fertilized eggs over the substrate. The spawning act is carried out at various intervals over 1 or 2 days. There is an erroneous record, often repeated, that the eggs are emitted in a long, gelatinous string. Eggs are about 2 mm in diameter, light yellow in colour, demersal, and slightly adhesive, sticking to the vegetation. The number of ripe eggs in Rhode Island females 12–14 inches (305–356 mm) in length has been estimated as 6102–8140 although a 1920 paper by Needham gave the number as 30,000 in a 2-pound female. Since eggs of three sizes are present in the ovary at any time, this latter may have been an estimate of all eggs. No care is given the eggs, which hatch in 6–12 days depending on temperature. The newly hatched young are 4.2–7.0 mm in length, with poorly developed mouths. They sink to the bottom where they attach themselves to vegetation by an adhesive gland on the tip of the snout. They subsist on yolk for about a week. By the time the yolk is absorbed, the young are about 10 mm long, the mouth is fully formed, and they begin active feeding. Mansueti and Hardy (1967) illustrated and described larval stages in the Chesapeake Bay region.

Growth is rapid in the first year. By the end of June in New York, young-of-the-year were 1.0–1.5 inches (25–38 mm) in length and by the end of September averaged 4 inches (102 mm) with some reaching nearly 5 inches (127 mm). Growth rate of young is extremely variable and in crowded situations considerable cannibalism may take place. McCabe (1942) recorded the age–length and age–weight relations for chain pickerel in Massachusetts as follows:

Age	Mean length		Mean wt
	(inches)	*(mm)*	*(oz)*
1	6.8	173	1.1
2	10.0	254	2.3
3	11.7	297	5.6
4	15.2	386	16.8
5	21.0	533	40.0
6	19.7	500	40.0
7	24.1	612	56.3
8	23.4	594	53.6

Comparable data for Cassidy Lake, N.B., is as follows:

Age	Range of TL (*mm*)	Wt
0	81–154	3.2–29.0 g
1	195–336	2.1–8.4 oz
2	240–392	3.6–18.5 oz
3	368–446	15.0–25.4 oz
4	429–450	25.1–29.0 oz
5	443	29.0 oz
6	519	48.0 oz

Average yearly growth increment in Massachusetts is 2.5 inches and 6.7 ounces.

Growth rate varies considerably from place to place and from year to year. Females apparently grow faster, mature sooner, live longer, and achieve a greater length.

Sexual maturity is reached by some in the first year in the south but most individuals mature in their third or fourth year in the north.

Average life span is 3 or 4 years with a maximum at 8 or 9 years depending on conditions and growth rate. Stroud (1955) cited chain pickerel from Massachusetts as large as 38.9 inches (922 mm) in standard length and 9 years of age.

Most chain pickerel seen are 15–18 inches (381–457 mm) in length, maximum length is usually cited as 30 inches (762 mm) and maximum weight about 6 pounds. Migdalski (1962) said that the largest authenticated chain pickerel was 29.5 inches (749 mm) in length and weighed 9 pounds 5 ounces. The angling record was an individual 31 inches (787 mm) in length and 9 pounds 6 ounces in weight, caught near Homerville, Ga., on February 17, 1961. A record in 1965 of a chain pickerel from Quebec that weighed 10 pounds 4 ounces might actually represent a hybrid chain pickerel × northern pike.

Chain pickerel are solitary fish, hiding almost motionless in the vegetation most of the time. The usual habitat is sluggish streams and heavily vegetated lakes and ponds with water often no deeper than 10 feet and summer surface water temperatures of 70°–86° F (21.1°–30.0° C). They may be able to live in water as warm as 98° F (36.7° C). Larger fish move into shallow water in the night, and into deeper water during the day. In summer they may establish a definite station or territory and leave it only when in pursuit of food. They sometimes move into brackish water in winter and are known to be able to live in water with salinities as high as 15‰, and in water as acid as *p*H 3.8. They are active and take food during the winter under the ice in slightly deeper water than in summer.

Chain pickerel are predaceous carnivores but type of food changes with size. The newly hatched feed exclusively on plankters for a week or more then on a wide variety of invertebrates but mostly immature aquatic insects and some small fish. After they reach a length of 4–6 inches (102–152 mm) fish become the principal item in the diet but larger invertebrates, such as crayfish, are still eaten. The fishes eaten will depend on what is most readily available, no selection is shown and one study reported 37 species. These were mainly minnows, sunfishes, and catfishes, but usually include chain pickerel and redfin pickerel. Other vertebrates such as snakes, mice, and frogs are eaten periodically, as is almost anything alive and small enough to be engulfed. Larger chain pickerel usually exhibit a direct size relation with the fishes eaten. Winter food is not greatly different from that taken in summer.

For chain pickerel the number of predators is limited by the habitat. Pickerel living in highly acid water and reaching 5.9 inches (150 mm) in length probably have few predators other than chain pickerel. In other habitats, and when smaller, a wide variety of fishes including basses, sunfishes, and yellow perch prey on them. Frogs, mergansers, grebes, loons, kingfishers, and herons are also listed as predators, along with man. When young, chain pickerel compete for food with all fishes in the habitat that depend on invertebrates. As predaceous piscivorous adults they may have few competitors especially in the acid water and smaller, shallow habitats. The choice of a spawning site probably is a limiting factor as eggs or young, or both, can be stranded by receding water levels.

Hoffman (1967) listed in detail 36 parasites that have been reported from this species. In summary these were Protozoa (4), Trematoda (17), Cestoda (5), Nematoda (5), Acanthocephala (3), leeches (1), Crustacea (1).

The chain pickerel hybridizes in nature with the redfin pickerel and the northern pike. The former cross is fertile and backcrosses of the F_1 and each parent have been described from several United States locations. Nonfertile hybrids between chain pickerel and northern pike are known from Quebec and New York (Crossman and Buss 1965).

Relation to man In Canada this species is not considered of great importance even in areas where it is abundant. In Quebec and New Brunswick a few find their way to local markets from the catches of hoopnet fishermen and are sold fresh. In Quebec the chain pickerel is not highly regarded as a sport fish, is rarely sought directly, but often kept if caught when fishing for other species. In New Brunswick chain pickerel are looked upon as something to tide the avid angler over the winter until better species are available or in season.

In some eastern seaboard states the chain pickerel is one of the most abundant species in ponds, favoured as a sport fish often second only to largemouth bass and actively sought after with small spoons, plugs, or live bait, by trolling, casting, still fishing, or skittering. They often constitute 4% by weight of the fish found in Massachusetts ponds. Production usually varies up to about 10 pounds/acre but can go as high as 67 pounds/acre when they are stocked in barren ponds with suitable forage fishes. In many places it is thought to taste weedy in summer; in winter it is considered a table delicacy. The flesh is good, tasty, white, and flaky, but best if skinned before cooking as it may be the mucus or pigments that contribute the unsatisfactory taste in summer. The value of this species as a control of the numbers of smaller fishes has never really been proven.

Chain pickerel are usually listed as sport fish and are covered by size and bag limits, if not by a closed season.

Nomenclature

Esox reticulatus — LeSueur 1818b: 414 (type locality Philadelphia. Holotype MNHN Paris 44.1.3.1 No. B961)
Esox reticulatus — Richardson 1836: 123
Lucius reticulatus (Le Sueur) — Jordan and Evermann 1896–1900: 627
Esox tridecemlineatus — Hubbs 1926: 53

No actual type locality is given for *Esox reticulatus* in Lesueur 1818, but Philadelphia is mentioned. The type locality has usually been cited in subsequent accounts as Saratoga Lake (New York) or South Carolina. The label with the type specimen says Philadelphia. This confusion resulted from the nomenclatorial problem that arose from the uncertainty over which species described by Lesueur in the same paper, *reticulatus* or *niger*, actually was the chain pickerel. Although *reticulatus* was the type, the name *reticulatus* was preoccupied, so *niger* was the next available name. Unfortunately it is not a good one as it was based on young specimens.

Etymology *Esox* — old European name for the pike; *niger* — black. The original description was based on young individuals which are often very dark in colour.

Common names Chain pickerel, pickerel, eastern pickerel, mud pickerel, grass pickerel, lake pickerel, reticulated pickerel, federation pickerel, pike, green pike, black chain pike, duck-billed pike, jack, snake, picquerelle. (*See* Weed 1927 for list.) French common name: *brochet maillé*.

Suggested Reading – Esocidae

BUSS, K. MS 1960. The muskellunge. Pa. Fish Comm. Benner Spring Fish Res. Sta. Spec. Sci. Rep. 14 p. (Mimeogr.)

MS 1961. The northern pike. Pa. Fish Comm. Benner Spring Fish Res. Sta. Spec. Sci. Rep. 58 p. (Mimeogr.)

MS 1962. A literature survey of the life history of the redfin and grass pickerels. Pa. Fish Comm. Benner Spring Fish Res. Sta. 12 p. (Mimeogr.)

CARBINE, W. F. 1942. Observations on the life history of the northern pike, *Esox lucius* L., in Houghton Lake, Michigan. Trans. Amer. Fish. Soc. 71: 149–164.

CROSSMAN, E. J. 1960. Variation in number and asymmetry in branchiostegal rays in the family Esocidae. Can. J. Zool. 38: 363–375.

CROSSMAN, E. J., and K. BUSS. 1965. Hybridization in the family Esocidae. J. Fish. Res. Bd. Canada 22: 1261–1292.

FABRICIUS, E., and K.-J. GUSTAFSON. 1958. Some new observations on the spawning behaviour of the pike, *Esox lucius* L. Rep. Inst. Freshwater Res. Drottningholm 39: 23–54.

FRANKLIN, D. R., and L. L. SMITH, JR. 1963. Early life history of the northern pike, *Esox lucius* L., with special reference to the factors influencing the numerical strength of year classes. Trans. Amer. Fish. Soc. 92: 91–110.

HOURSTON, A. S. 1955. A study of variations in the maskinonge from three regions in Canada. Contrib. Roy. Ont. Mus. Zool. Palaeontol. 40: 13 p. + 4 tables, 16 pl.

KARVELIS, E. G. 1964. The true pikes. U.S. Fish. Wildl. Serv. Fish. Leafl. 569: 11 p.

KENDALL, W. C. 1917. The pikes: their geographical distribution, habits, culture, and commercial importance. Rep. U.S. Fish. Comm. (1917), Bur. Fish. Doc. 853: 1–45.

KLEINERT, S. J., and D. MRAZ. 1966. Life history of the grass pickerel (*Esox americanus vermiculatus*) in southeastern Wisconsin. Wis. Conserv. Dep. Tech. Bull. 37: 40 p.

LINCOLN, R. P. 1953. The pike family. The Stackpole Co., Harrisburg, Pa. 274 p.

LIND, J. A. 1964. Muskie! McCormick and Henderson, Inc., Chicago, Ill. 204 p.

MING, A. D. 1968. Life history of the grass pickerel, *Esox americanus vermiculatus*, in Oklahoma. Okla. Fish. Res. Lab. Bull. 8: 66 p.

OEHMCKE, A. A., L. JOHNSON, J. KLINGBIEL, and C. WISTROM. 1958. The Wisconsin muskellunge. Its life history, ecology, and management. Wis. Conserv. Dep. Publ. 225: 12 p.

SMITH, O. W. 1922. The book of pike. Stewart Kidd and Co., Cincinnati, Ohio. 197 p.

SOLMAN, V. E. F. 1945. The ecological relations of pike, *Esox lucius* L., and waterfowl. Ecology 26: 157–170.

THREINEN, C. W., C. WISTROM, B. APELGREN, and H. SNOW. 1966. The northern pike, its life history, ecology, and management. Wis. Conserv. Dep. Publ. 235: 16 p.

WEED, A. C. 1927. Pike, pickerel, and muskalonge. Field Mus. Natur. Hist. Zool. Leafl. 9: 52 p.

THE MINNOWS OR CARPS — Order Cypriniformes (Ostariophysi)

Fishes of variable size and shape, resembling, in most basic respects, the clupeiform fishes but differing from them in one very special character: the first 4 anterior vertebrae are modified to form a complex known as the Weberian apparatus, which consists of a series of bony ossicles connecting the swim bladder with the inner ear. The skull, like the body form, varies widely but is basically of the clupeiform type; orbitosphenoid, and usually mesocoracoid, present; jaws may be weak and toothless or strong with well-developed teeth, upper jaw often bordered by premaxillae and maxillae. Branchiostegals 3–20. All fins usually without spines, but 1 or 2 specially derived spines occur in certain groups in dorsal, anal, or pectoral fins; always one, rayed dorsal fin but some groups also have an adipose dorsal fin; caudal fin homocercal; no vertebrae upturned; 1 anal fin; pelvic fins abdominal and many rayed (when present), pelvic girdle not attached to cleithrum; pectoral fins located more or less ventrally, behind head, the bases nearly or quite horizontal. Scales cycloid, modified into bony plates, or absent. Physostomes. Vertebrae numerous and modified anteriorly (*see* above).

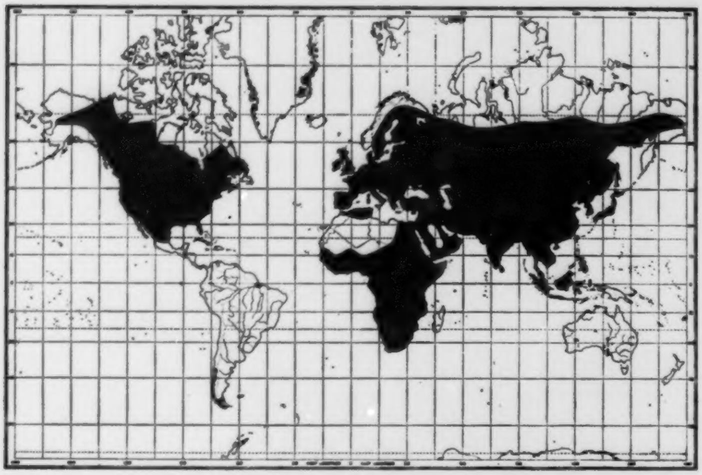
The cypriniform fishes are one of the largest and most important groups of fishes in the world, second only in numbers and faunal dominance to the Perciformes, and whereas the latter dominate the seas, the cypriniforms dominate the fresh waters. They are usually of prime importance in the fresh waters of all continents except Australia. In Canada, they occur in large numbers in the southern parts where they have managed to gain access in postglacial times, but the salmonoid fishes dominate the cool, boreal, fresh waters of northern Canada.

The order is usually classified in 2 suborders, 33 families, and about 5000 species. Three families and 68 species occur in Canadian fresh waters.

MINNOW OR CARP FAMILY — Cyprinidae

The minnows or carps are small to large fishes of variable body shape, but North American forms are generally elongate and resemble each other in general appearance. Mouth small or large, terminal, subterminal or inferior in position; jaws toothless; upper jaw bordered by premaxilla only; 1 or 2 pairs of barbels sometimes present; lower, pharyngeal bones with 1–3 rows of teeth, which grind food against a pair of horny pads attached to the basioccipital. Gill membranes united. Branchiostegals 3. Fins of North American forms all soft rayed (except the stiffened first or second rays of dorsal and anal fins of genera *Meda*, *Lepidomeda*, and *Plagopterus*, and the introduced *Carassius* and *Cyprinus*); no adipose fin. Scales cycloid, restricted to body; lateral line usually present. Sexual dimorphism often conspicuous, breeding males may display bright colours and have nuptial tubercles on head, body, and fin rays.

The minnows and carps, freshwater fishes of Africa, Europe, Asia, and North America, include some 275 genera and over 1500 species, and thus make the Cyprinidae the largest of all fish families. They are frequently called primary freshwater fishes, in reference to their dependence on a freshwater environment and their intolerance of salt water. Forty-four species (3 introduced from Europe) occur in Canadian waters. Known from Paleocene of Europe, Eocene of Asia, and Miocene of North America.



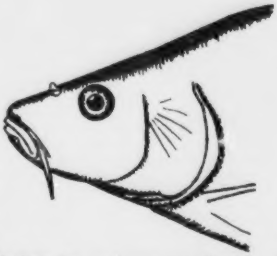
World Distribution of the Minnows or Carps

Ichthyologists, like other life scientists, are constantly seeking to improve classifications and, especially, to uncover evidence of closer relationships between genera or species, but sometimes decisions are made before all the evidence is in. In recent years the monotypic genus *Hyborhynchus* gave way to critical study and was demonstrated to be not significantly different from *Pimephales*. Similar action took place with *Pfrille*, which was submerged in *Chrosomus* in recent years. At the time of writing the American Fisheries Society publication (1970), *A list of common and scientific names of fishes from the United States and Canada* places *Chrosomus* in the synonymy of *Phoxinus*, a widely distributed genus of Eurasian cyprinid. However such action seems unwarranted, at least until a reasonably thorough study has been undertaken and the results made available for all to consider. Snap decisions based on insufficient evidence do not make for good science especially if urgent action is unnecessary. The names of many North American fishes have been subjected to such changes, yoyo fashion, all too frequently in recent years (viz *Couesius* to *Hybopsis* to *Couesius*; *Nocomis* to *Hybopsis* to *Nocomis*) to the confusion of all but systematic ichthyologists and even some of them have to resort to common names to communicate.

KEY TO SPECIES[1]

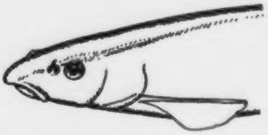
1 **Dorsal fin base long, more than 11 soft dorsal rays; dorsal and anal fins each with strong spine, serrated on trailing edge** 2

Dorsal fin base short, fewer than 11 soft dorsal rays (except *Acrocheilus alutaceus* and *Richardsonius balteatus*, which may occasionally have 11 rays); no spines in fins 3

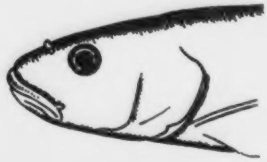


2 **Two pairs of long barbels on upper jaw; pharyngeal teeth molarlike (1,1,3–3,1,1); gill rakers 21–27; scales in lateral line usually more than 32 (mirror and leather carp are only partially scaled)** .... **CARP, *Cyprinus carpio* (p. 407)**

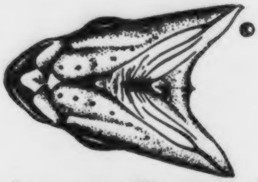
Barbels absent; pharyngeal teeth not molarlike (4–4); gill rakers 37–43; scales in lateral line usually less than 32 .... **GOLDFISH, *Carassius auratus* (p. 389)**



3 **Premaxillaries not protractile (i.e., no groove across snout in midline)** 4



Premaxillaries protractile (i.e., with groove across snout) 6



4 **Lower jaw conspicuously trilobed, its centre lobe tongue shaped; body not obviously speckled or blotched; body stout** .... **CUTLIPS MINNOW, *Exoglossum maxillingua* (p. 412)**

Lower jaw of normal shape; body flecked with darkened scales or speckled; body streamlined 5

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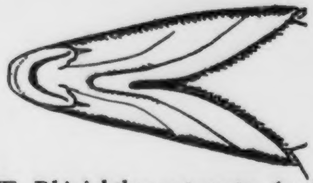
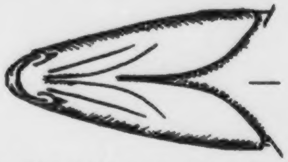
[1] *Campostoma anomalum*, the stoneroller, was reportedly caught in the Lake St. Clair drainage of Ontario in 1972.



5 Snout long, projecting far beyond mouth; lateral band indistinct or absent (except on young-of-the-year) .... LONGNOSE DACE, *Rhinichthys cataractae* (p. 494)

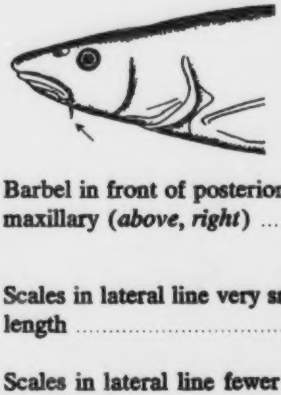


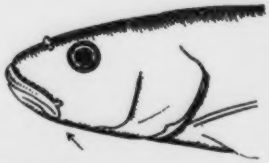
Snout scarcely projecting beyond mouth; lateral band prominent; rusty red lateral band on spawning males .... BLACKNOSE DACE, *Rhinichthys atratulus* (p. 491)

6 Maxillary with barbel (sometimes concealed in maxillary groove) 7

Maxillary without a barbel 16

7 Barbel terminal and slender, at or near end of maxillary (*below, left*) 8





Barbel in front of posterior end of upper jaw, often hidden in groove above maxillary (*above, right*) 23

8 Scales in lateral line very small, 90 or more; body deep, about 25% of total length .... TENCH, *Tinca tinca* (p. 519)

Scales in lateral line fewer than 80; body depth moderate, 20% or less of total length 9

9 Mouth large, gape extending to below anterior margin of eye; pectoral fins long, narrowed, and pointed, tips reaching to anterior base of pelvic fins or nearly so; lateral line scales 48–59 ....
.... FLATHEAD CHUB, *Platygobio gracilis* (p. 484)

Mouth moderate to small, gape not extending to anterior margin of eye; pectoral fins rounded or bluntly pointed, not reaching base of pelvic fins 10

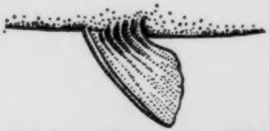
10 Lateral line scales 52 or more 11

Lateral line scales less than 50 13

11 Lateral line scales 68–79; pelvic axillary scale well developed .... PEAMOUTH, *Mylocheilus caurinus* (p. 424)

Lateral line scales 52–65; pelvic axillary scale absent or weakly developed 12

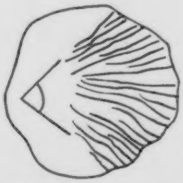
12 No fleshy stays on dorsal aspect of pelvic fins; lateral line scales 54–65; body sometimes with specialized darkened scales .... LAKE CHUB, *Couesius plumbeus* (p. 401)



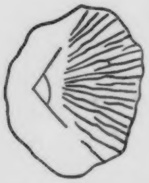
Conspicuous fleshy stays on dorsal aspect of pelvic fins, joining fin rays to body; body conspicuously speckled; lateral line scales 52–57 .... LEOPARD DACE, *Rhinichthys falcatus* (p. 498)

13 Snout projecting only slightly beyond mouth 14

Snout projecting considerably beyond mouth 15



14 Angle enclosed by scale radii about 70–75°; caudal spot large and distinct; snout length into standard length more than 9 times; distinct mid-dorsal line and lateral band .... HORNYHEAD CHUB, *Nocomis biguttatus* (p. 427)



Angle enclosed by scale radii 95–105°; no caudal spot; snout length into standard length 8 times or less; no mid-dorsal line; lateral band indistinct .... RIVER CHUB, *Nocomis micropogon* (p. 431)

15 Body with X-shaped dark spots, only faintly evident on Ontario specimens .... GRAVEL CHUB, *Hybopsis x-punctata* (p. 423)

Body without definite spots; scales large and deciduous; lower 3 or 4 rays of caudal fin unpigmented .... SILVER CHUB, *Hybopsis storeriana* (p. 420)

16 Lateral line scales more than 55 17

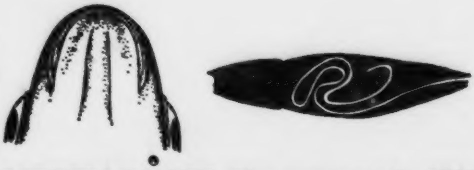
Lateral line scales 54 or fewer 25

17 Mouth terminal, not overhung by snout; gape small or large 18

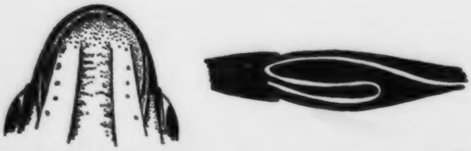
Mouth inferior, overhung by snout; gape small 22

18 Peritoneum black; lateral line incomplete; body robust, not noticeably compressed; size small, to about 3 inches (76 mm) 19

Peritoneum silvery or speckled, not black; lateral line complete; body laterally compressed or elongate, and pike-like; size larger, to 3.5 inches (89 mm) or more 20



19 Intestine with 2 crosswise coils in addition to main loop; mouth small, terminating distinctly in advance of eye; a dark line, entire or broken, between lateral band and back .... NORTHERN REDBELLY DACE, *Chrosomus eos* (p. 392)



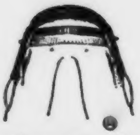
Intestine shorter, with single main loop; mouth larger, extending almost to below anterior margin of eye; back uniformly pigmented .... FINESCALE DACE, *Chrosomus neogaeus* (p. 396)

20 Pelvic fin origin not in advance of dorsal fin, dorsal inserted over pelvic fin origin; body elongate, not markedly compressed; young with small but precise black spot at caudal base .... NORTHERN SQUAWFISH, *Ptychocheilus oregonensis* (p. 487)

Pelvic fin origin in advance of dorsal fin origin; body laterally compressed; no black spot at caudal base 21

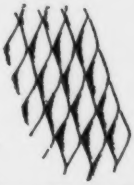
21 Dorsal rays 9 or 10 (seldom 8); anal rays 10–22, usually 15; snout short, less than eye diameter .... REDSIDE SHINER, *Richardsonius balteatus* (p. 503)

Dorsal rays 8, rarely 7; anal rays 9 (seldom 8 or 10); snout long and pointed, greater than eye diameter .... REDSIDE DACE, *Clinostomus elongatus* (p. 399)



22 Lower jaw with a hard and almost straight cutting edge (like a chisel); anal rays 9 or 10; peritoneum jet black .... CHISELMOUTH, *Acrocheilus alutaceus* (p. 386)

Lower jaw with fleshy lip, mouth suckerlike; anal rays 6 or 7; peritoneum dark brown .... SPECKLED DACE, *Rhinichthys osculus* (p. 501)



23 Scales in lateral line fewer than 50; young with distinct midlateral black band; each scale with dense pigment anteriorly .... FALLFISH, *Semotilus corporalis* (p. 511)

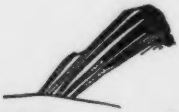
Scales in lateral line more than 50; scales without black pigment anteriorly 24

24 A black spot near anterior base of dorsal fin, sometimes indistinct in young; upper jaw extending to vertical through front of eye; lateral line scales 52–62; silvery, no distinct spawning colour .... CREEK CHUB, *Semotilus atromaculatus* (p. 507)

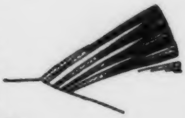
No black spot on dorsal fin; upper jaw not reaching a vertical through front of eye; barbel often small or absent; lateral line scales 65–75; sides often with scattered, darkened scales; spawning males with red on flanks and belly .... PEARL DACE, *Semotilus margarita* (p. 515)

25 Abdomen behind pelvic fins with a fleshy keel lacking scales; lateral line strongly decurved, following ventral outline of body; anal fin rays 12 or 13 .... GOLDEN SHINER, *Notemigonus crysoleucas* (p. 434)

Abdomen behind pelvic fins rounded over and scaled; lateral line not strongly decurved; anal fin rays usually less than 12 26



26 A dark spot (sometimes faint) at front of dorsal fin, slightly above base; back flattish; first dorsal ray separated by membrane from first well-developed ray; predorsal scales small, crowded 27



No dark spot at front of dorsal fin above base (a dark pigmented area at anterior base in *Notropis umbratilis*); back scarcely flattened; first dorsal ray closely attached to first well-developed ray; predorsal scales usually large and distinct 28

27 Lateral line incomplete; caudal spot faint; mouth terminal but small .... FATHEAD MINNOW, *Pimephales promelas* (p. 480)

Lateral line complete; a distinct caudal spot; mouth subterminal .... BLUNTNOSE MINNOW, *Pimephales notatus* (p. 476)

28 Mouth very small and nearly vertical; dorsal fin rays typically 9 .... PUGNOSE MINNOW, *Notropis emiliae* (p. 453)

Mouth larger; dorsal fin rays typically 8 29

29 Anal fin rays 9–12 (rarely 8, but 25% of *Notropis cornutus* populations may have only 8 rays) 30

Anal fin rays 7 or 8 (rarely 6 or 9) 33

30 Origin of dorsal fin over, or in front of, vertical through insertion of pelvic fins; lateral scales twice as high as wide; lower fins of males red during spawning .... COMMON SHINER, *Notropis cornutus*[2] (p. 448)

Origin of dorsal fin behind vertical through insertion of pelvic fins; scales round or nearly so 31

31 Body deep, depth equal to, or more than, length of head; dorsal fin with black pigmented area at anterior base; sides stippled with pigment; spawning males have bluish body, and rosy lower fins .... REDFIN SHINER, *Notropis umbratilis* (p. 472)

Body slender, depth equal to or less than length of head; no black spot at base of dorsal fin 32

32 Snout sharp, its length more than two-thirds distance from posterior margin of eye to posterior margin of gill cover; pigmentation on sides usually bordered below by lateral line .... ROSYFACE SHINER, *Notropis rubellus*[3] (p. 463)

Snout blunt, its length less than two-thirds distance from posterior margin of eye to posterior margin of gill cover; pigmentation on sides terminating above lateral line .... EMERALD SHINER, *Notropis atherinoides* (p. 440)

[2] *Notropis chrysocephalus* has been described as a species distinct from *N. cornutus* — chin usually pigmented; predorsal, dorsolateral scale rows 13–16 in *chrysocephalus*: chin usually unpigmented; predorsal, dorsolateral scale rows 18–24 in *cornutus*. *See* C. R. Gilbert (1964), Bull. Fla. State Mus. Biol. Ser. 8(2): 95–194, and R. J. Miller (1968), Copeia 1968: 640–647, for opposing opinions.

[3] The silver shiner *Notropis photogenis* was reportedly caught in the Grand River, Ont. in 1971. A report by C. G. Gruchy, R. H. Bowen, and I. M. Gruchy is now in press. *N. photogenis* resembles *N. rubellus* and *N. atherinoides* but may be distinguished from them in having the origin of the dorsal fin directly above the insertion of the pelvic fin.

33 Intestine short, with single main loop; mouth usually terminal (subterminal for *Notropis blennius* and *Notropis hudsonius*) 34

Intestine elongate, coiled on right side; mouth subterminal 42

34 Dorsal fin with black blotch on membranes between posterior rays (except in young); eye usually less than one-quarter, always less than one-third, length of head in adults; snout sharp or pointed .... SPOTFIN SHINER, *Notropis spilopterus* (p. 466)

Dorsal fin without black blotch on membranes between posterior rays; eye more than one-quarter length of head in adults; snout not sharp or pointed 35

35 Lateral band indistinct or absent, sometimes diffuse posteriorly; body somewhat compressed and deep; mouth subterminal 36

Lateral band usually distinct (less so on *Notropis volucellus* and *Notropis stramineus*), often extending onto head; body slender; mouth usually terminal 37

36 A large, conspicuous black spot at base of caudal fin (particularly obvious on young); scales in lateral line 38–42; anal rays 8 .... SPOTTAIL SHINER, *Notropis hudsonius* (p. 459)

No black spot at caudal base; scales in lateral line 38–45; anal rays 7 .... RIVER SHINER, *Notropis blennius* (p. 446)

37 Lateral band usually dark and obvious, continued forward through eye and onto snout; lateral line complete or incomplete 38

Lateral band weakly developed or dusky, not continued forward through eye; lateral line complete 41

38 Mouth very small, almost vertical; upper jaw extending only to vertical through nostril; lateral line nearly or quite complete; peritoneum black .... PUGNOSE SHINER, *Notropis anogenus* (p. 438)

Mouth larger, upper jaw reaching beyond a vertical through nostril almost to below eye; peritoneum silvery 39

39 Lateral band on chin (chin black), and on premaxillaries .... BLACKCHIN SHINER, *Notropis heterodon* (p. 454)

Lateral band on snout, but not on chin (chin not black) 40

40 Anal rays typically 8, sometimes 7; dorsal fin located over or behind a vertical through pelvic insertion; lateral line complete .... BLACKNOSE SHINER, *Notropis heterolepis* (p. 456)

Anal rays typically 7, sometimes 8; dorsal fin inserted over or before a vertical through pelvic insertion; lateral line incomplete .... BRIDLE SHINER, *Notropis bifrenatus* (p. 444)

41 Anal rays usually 8 (sometimes 9); black pigment about anus and base of anal fin; pigmentation extending below lateral line; no distinct mid-dorsal stripe .... MIMIC SHINER, *Notropis volucellus*[4] (p. 473)

Anal rays usually 7; little or no black pigment about anus or base of anal fin, nor below lateral line, thin but distinct mid-dorsal stripe .... SAND SHINER, *Notropis stramineus*[4] (p. 469)

42 Dorsal fin rounded; scales with about 20 radii in adult; colour brassy .... BRASSY MINNOW, *Hybognathus hankinsoni* (p. 414)

Dorsal fin somewhat falcate; scales with about 10 radii in adult; colour silvery .... SILVERY MINNOW, *Hybognathus nuchalis* (p. 417)

Table of meristics for the species of *Notropis*

	No. and range of rays					
	Dorsal	Anal	Pelvic	Pectoral	No. of vertebrae	Pharyngeal tooth formula
Notropis anogenus	8(7–8)	8(7–8)	8(7–8)	12(11–13)	32–36	0,4–4,0
Notropis atherinoides	8(7–8)	11(10–13)	8(8–9)	15(13–17)	38–41	2,4–4,2
Notropis bifrenatus	8(7–8)	7(7–8)	8(7–8)	12(11–13)	34–36	0,4–4,0
Notropis blennius	8(7–8)	7	8	14(13–15)	36–37	2,4–4,2
Notropis cornutus	8	9(8–10)	8(8–9)	16(15–17)	38–43	2,4–4,2
Notropis dorsalis	8	8	8	14–15	34–37	1,4–4,1
Notropis emiliae	9	8	8	15	37–38	0,5–5,0
Notropis heterodon	8(7–8)	7(7–8)	8(7–8)	12–14	35–36	1,4–4,1
Notropis heterolepis	8(7–9)	8(7–8)	8(7–8)	12(12–14)	34–36	0,4–4,0
Notropis hudsonius	8(8–9)	8(7–8)	8(7–8)	14(12–17)	37–39	2,4–4,2
Notropis rubellus	8(7–8)	10(9–11)	8	12(11–14)	37–41	2,4–4,2
Notropis spilopterus	8(7–8)	8(7–9)	8(7–9)	13(12–15)	37–39	1,4–4,1
Notropis stramineus	8	7(6–8)	8	13(12–16)	33–36	0,4–4,0
Notropis umbratilis	8(7–8)	11(10–12)	8(7–9)	12–13	35–36	2,4–4,2
Notropis volucellus	8	8(8–9)	9(8–10)	15(12–16)	34–37	0,4–4,0

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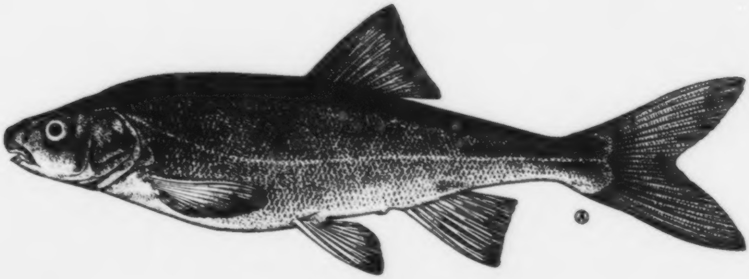
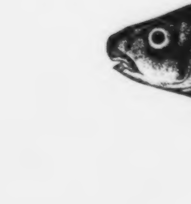
[4] If mouth large, dorsal stripe heavier than a thin line, and anal rays 8, specimen may be *Notropis dorsalis*, recently recorded from southern Manitoba.

CHISELMOUTH

Acrocheilus alutaceus Agassiz and Pickering





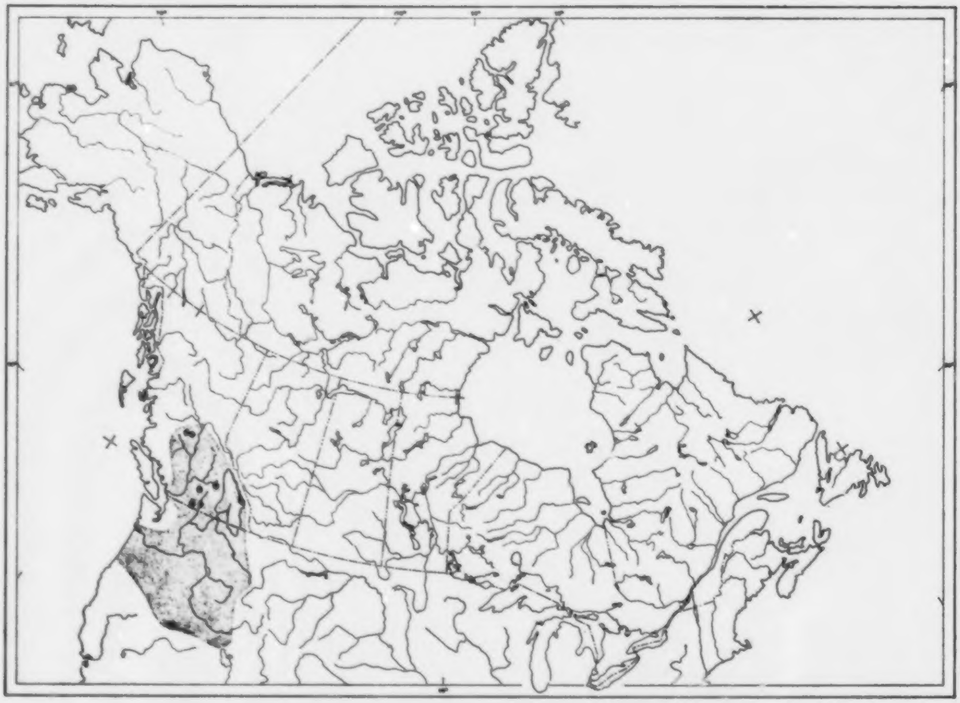
Description Body elongate, average total length 6–7 inches (152–178 mm), robust, only slightly compressed, body depth 17–20% of total length, caudal peduncle slender, appearing as if pinched posteriorly, its least depth 5.3–6.3% of total length. Head blunt, its length approximating body depth, 17.4–18.9% of total length; eye relatively large, especially in immatures, its diameter 20.9–32.1% of head length; snout bluntly rounded, its length 28.5–33.3% of head length; interorbital broad, its width 37.2–42.8% of head length; mouth inferior, overhung by snout, fleshy upper lip covers small cartilagineous plate in upper jaw, but lower lip covered with a hard cartilagineous sheath, with an almost straight-cutting edge (like a chisel), except in young; pharyngeal teeth stout, hooked, grinding surface dependent on age, Carl et al. (1967) said 4–5 or 5–5, but La Rivers (1962) gave 5–4, seldom 5–5. Gill rakers about 13–17. Fins: dorsal 1, origin behind origin of pelvic fin, rays usually 10; caudal distinctly forked; anal fin origin behind insertion of dorsal fin, rays 9(5) or 10(1); pelvics well developed, rather narrow, 9 or 10 rays; pectorals with 15–18 rays. Scales cycloid, small, embedded, 85–93 in lateral line; lateral line complete. Peritoneum intensely black; intestine at least twice body length. Vertebrae 44 or 45.

Colour Overall colouration rather drab, dark brown above, sides lighter but with many small black dots, and lighter below; young fish with a vague black spot at caudal fin base. Sometimes with orange colouration in axils of pectoral and pelvic fins.

Systematic notes Miller and Smith (1967) described a new species, *Acrocheilus xestes*, from fossil remains recovered from a Cenozoic locality in Idaho. It possibly ranged in Idaho during the late Pliocene and early Pleistocene. *See* Miller and Smith for details.

Distribution The chiselmouth is confined to the Pacific drainage systems of the Fraser and Columbia rivers, and Malheur Lake in Oregon. It occurs in Nevada, Idaho, Oregon, Washington, and British Columbia.

In Canada it has been reported only from British Columbia as follows: Euchiniko and Nazko rivers, and Nicola Lake of the Fraser River system; Missezula, Wolfe, Skaha, Gallagher, and Tugulnuit lakes, and the Okanagan River of the Okanagan–Columbia system; and Windermere Lake in the Kootenay–Columbia system (Carl et al. 1967). In Canada, it occurs more often in lakes than rivers.



Biology There appears to be little information available on reproduction or growth rate of the chiselmouth.

G. E. E. Moodie (1966) studied the chiselmouth in British Columbia waters as part of a M.Sc. program and his work provides the only detailed account of this species in Canadian waters. The following biological information has been derived primarily from Moodie's unpublished report, which resulted mainly from study of a population in Wolfe Lake, near Princeton, on the Similkameen River system, B.C.

Spawning of lake populations occurred in tributary streams as far as 1.5 km upstream, usually in late June and early July, but only at a temperature of about 62.5° F (17° C) or higher. Moodie was unable to observe actual spawning, but found eggs on the open bottom and also buried among boulders. The mean egg count for six females was 6200.

Newly hatched larvae are about 8.1 mm long. From the time of yolk absorption until 15 mm long, they are difficult to distinguish from other cyprinids, but over this size the characteristic mouth is apparent. The identification of young may be complicated further by the occurrence of hybrids (Patten 1960).

Growth data obtained by Moodie were not entirely satisfactory. Otoliths were used for age determination but a high percentage were considered to be unreadable. Males probably attain sexual maturity and spawn at age 3, females sometimes at age 3 but usually age 4. The maximum age noted was 6 years, when a fork length of about 8.8 inches (225 mm) was attained.

Feeding by adults is very specialized and consists of scraping the chisel-like lower jaw along rocks or other bottom substrate, usually for only a short distance of 2.0–2.5 cm. The unique feeding behaviour consists of very quickly executed darting dives on algae-covered substrates. Large quantities of filamentous green algae and diatoms are ingested by the chiselmouth, but Moodie found no evidence that filamentous algae was digested, even to a minor degree. He concluded that diatoms constitute the major food of adults. Young chiselmouths, from 0.8 to 3.9 inches (20–100 mm) long, feed largely on surface insects.

Moodie noted that the diet of young chiselmouths and young squawfish is similar and, hence, some competition might occur at this stage in the life history.

The only published report on the parasites of the chiselmouth in Canada seems to be that of Bangham and Adams (1954), who examined a total of 32 specimens from British Columbia waters, 24 of these from the Okanagan River. The nematode *Rhabdochona cascadilla* was the most common parasite, then the trematodes *Posthodiplostomum minimum*, *Neascus* sp., and Gyrodactyloidea. Additional information on parasites was provided by Hoffman (1967).

Relation to man Although direct information appears to be lacking, the chiselmouth seems to be of little economic significance. Biologically it is of considerable interest because of the peculiar adaptation of the upper and lower jaw, which permits it to make a living in a unique manner by scraping algae from stones.

La Rivers (1962) reported that in former times it was said to have been used for aboriginal food.

Nomenclature

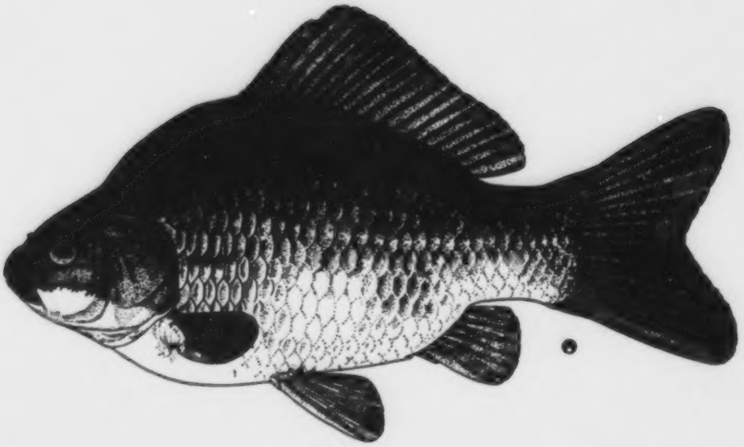
Acrocheilus alutaceus Agass. and Pick. — Agassiz 1855: 99 (type locality Willamette Falls and Wallawalla River, Ore.)
Lavinia alutacea — Girard 1857a: 184
Acrochilus alutaceus — Günther 1868: 276
Acrocheilus alutaceum — La Rivers 1952: 98

Etymology *Acrocheilus* — sharp; lip; *alutaceus* — leathery.

Common names Chiselmouth, hardmouth, squaremouth. French common name: *bouche coupante*.

GOLDFISH

Carassius auratus (Linnaeus)



Description Body stout, thickset, average total length about 5–10 inches (127–254 mm), caudal peduncle thick and short (stockier than carp of same length), body depth 28–34% of total length. Head broadly triangular, its length 24.1–26.4% of total length; eye moderate, its diameter 19.0–31.8% of head length; snout relatively short, 25.0–36.8% of head length; interorbital broad, its width 35.7–42.8% of head length; mouth relatively small, protrusible, without barbels; pharyngeal teeth 0,4–4,0. Gill rakers 37–43. Fins: heavy, translucent, usually same colour as body; dorsal 1, base long, of 1 stout spine with serrated trailing edge, and 15–18 (usually 17) soft rays; caudal broadly forked; anal 1, base short, of 1 stout spine with serrated trailing edge and 5 or 6 (usually 5) soft rays; pelvics short, broad, thoracic in position, the soft rays 8 or 9 (usually 9); pectorals broad, 15–17 soft rays. Scales cycloid, large, rather firmly attached, 27–30 in the lateral line; lateral line complete. Vertebrae usually 28 or 29.

Nuptial tubercles fine, on opercles, sometimes on back, and a few on pectoral fins of breeding male.

Colour Overall colouration variable, from olive-green through gold (often with black blotches) to creamy white. Young fish are green, brown, greyish bronze, or almost black. The young of cultured, gold-coloured stock are not gold, but often very dark, almost black, attaining the golden colour in 8–12 months. Goldfish are selectively bred for colour, but when such stock is released and allowed to "go wild," they usually revert to olive-green colouration, although some fish show patches of gold, white or black or both, and some may be almost all white. As interbreeding continues, the highly coloured fish become more rare, partly as a result of selective predation by fish-eating birds, such as herons.

Systematic notes Goldfish hybridize readily with carp, and such individuals may be difficult to identify for they may show a blending of parental characters. The major features distinguishing goldfish from carp are: absence of barbels, pharyngeal teeth not molarlike and in a single row, and gill rakers about 37–43.

Distribution Native to eastern Asia, goldfish originated in China. Hervey and Hems (1968), in their extensive study of this species, stated that they appeared as pets in the early days of the Sung Dynasty, about the year 960, and from the 11th century onward they were popular household pets. There appears to be some doubt of the time of introduction to Japan. Some authorities say about the year 1500, but Okada (1959–1960) discussed this question and showed that the available evidence suggests dates ranging from 1502 to 1748. In the early years of the 18th century, or late 17th century, they were introduced into England, and by the middle of the 18th century were widespread there. Introductions into other parts of Europe took place about the same time.

It is not known definitely when goldfish were brought to America, but by 1889 a goldfish farm was established in Maryland, and they are now widespread throughout the United States.

In Canada distribution is sporadic. They are unknown in the Maritime Provinces, and, according to V. Legendre (personal communication 1967) they had not become established in Quebec waters.

They are reported to occur in Ontario in Lake St. Clair, Detroit River, and various parts of Lake Erie, and may occur in any small, shallow lake in southern Ontario (such as Musselman's Lake) and in ponds in High Park, Toronto, as a result of release of domestic stock (Scott 1967). A population has persisted in Gillies Lake, near Timmins, Ont., for many years.

Thus far, there are no reports of occurrences in Manitoba, but it is to be expected that goldfish will find their way into that province from the Cheyenne River, N.D., a tributary of the Red River (Fedoruk 1969).

It has not been reported from Saskatchewan waters to date.

Paetz and Nelson (1968) stated that several releases of goldfish have been made in Alberta, and that there is a population in Henderson Lake, at Lethbridge.

In British Columbia they are known to be present in a large pond at Salmon Arm, and in a small lake in the Kamloops district. Carl et al. (1967) stated that the Salmon Arm population was first noted in 1935 and had increased tremendously by 1941.

Biology Like the carp, the goldfish is a spring-spawning species and seeks warm, weedy shallows in May or June to deposit its eggs. Battle (1940) found developing eggs as late as August 17 in Lake Erie. The spawning behaviour of the goldfish is generally not accompanied by as much splashing as that of the carp, in part because of the smaller size of the goldfish. The female may be accompanied by two or more males, and the eggs released over submerged aquatic plants or willow roots. Spawning most often occurs on bright sunny mornings.

The eggs are adhesive, 1.2–1.5 mm in diameter, and hatch in about 3 days or more, depending on temperature. Battle (1940) provided a thorough description of the embryology and development and gave the following incubation times: 3–4 days at 65.3°–85.1° F (18.5°–29.5° C); 64–72 hours at 75.2°–82.4° F (24°–28° C); 76 hours at 77° C (25° C). Young goldfish vary greatly in colour but are often green or brown. Mansueti and Hardy (1967) also illustrated and described larval stages in the Chesapeake Bay region.

The artificial culture of goldfish has been practiced by man for centuries and is the subject of extensive literature in many languages. For comprehensive coverage *see* especially Hervey and Hems (1968).

Goldfish have not been so successful as carp in establishing themselves in natural waters. They seem to have been most successful in small bodies of water, such as ponds, and often where there is a good growth of aquatic plants. They do not grow nearly so large as carp but are heavier at a given length. The following figures were obtained from wild specimens taken from Silver Lake, Port Dover, Ont.:

Fork Length		Weight	
(inches)	*(mm)*	*(oz)*	*(g)*
8.75	222	12	340
9.0	229	14	397
10.25	260	18	510
10.5	267	24	680

Goldfish are omnivorous feeders consuming a variety of larvae and adult aquatic insects, molluscs (such as small clams and snails), crustaceans, aquatic worms, and aquatic vegetation.

There are many reports treating the parasite fauna of European and Asiatic goldfish but these are of little concern here. For Lake Erie wild goldfish, however, Bangham and Hunter (1939) reported nematodes and acanthocephalans. Goldfish retained in artificial ponds are often more prone to parasites and to diseases than wild fish, possibly due in part to crowding and minimal predation.

Relation to man The use of goldfish as pets or to provide colour in ornamental ponds has been a part of man's culture for so many hundreds of years that no elaboration is necessary. Almost every dime store has a goldfish counter and a supply of variously shaped goldfish bowls and, with almost equal frequency, a supply of unsuitable food. For information on this aspect *see* especially Innes (1947), Sterba (1962), Hervey and Hems (1968). The most recently advertised use of goldfish to stock ornamental ponds occurred in 1969–1970 when wild goldfish from ponds in High Park, Toronto, were sent to Japan to stock the large pool in Canada's pavilion at Expo 70.

Goldfish are widely used as laboratory animals, for example, in physiological work developing techniques in measuring sensitivity to, and rate of uptake of, various dissolved gases such as carbon dioxide and oxygen, sensitivity to temperature, measuring swimming speeds, and toxicity to various industrial wastes. The goldfish is the aquatic counterpart of the guinea pig and the rabbit.

Although not usually regarded as a commercial species, they hybridize with carp and such hybrids and large (green-coloured) goldfish are marketed along with carp. In parts of Canada, where laws concerning live bait or baitfish exist, both the goldfish and carp are expressly prohibited for use as bait, but this is not so in parts of the southeastern United States. Dobie et al. (1956) provided information on raising goldfish for live bait use in such regions.

Nomenclature

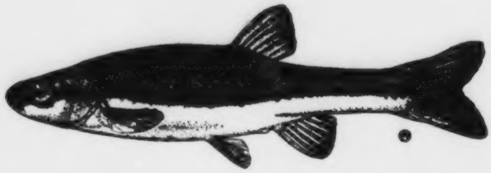
Cyprinus auratus	— Linnaeus 1758: 322 (type locality China, Japan, rivers)
Carassius auratus	— Günther 1868: 32

Etymology *Carassius* — Latinization of the vernacular names Karass or Karausche, applied to the European crucian carp *C. carassius*; *auratus* — gilded.

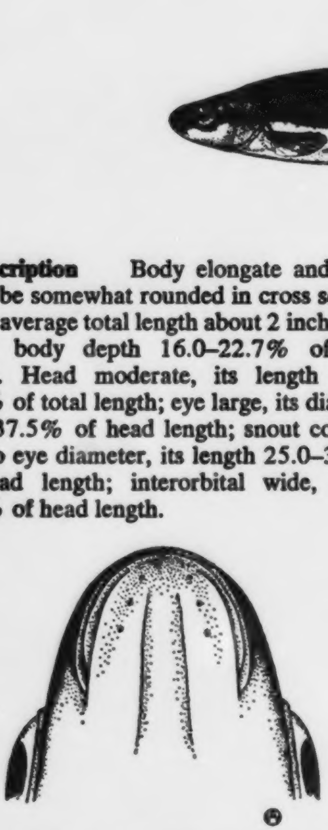
Common names Goldfish, golden carp. French common name: *poisson doré*.

NORTHERN REDBELLY DACE

Chrosomus eos Cope



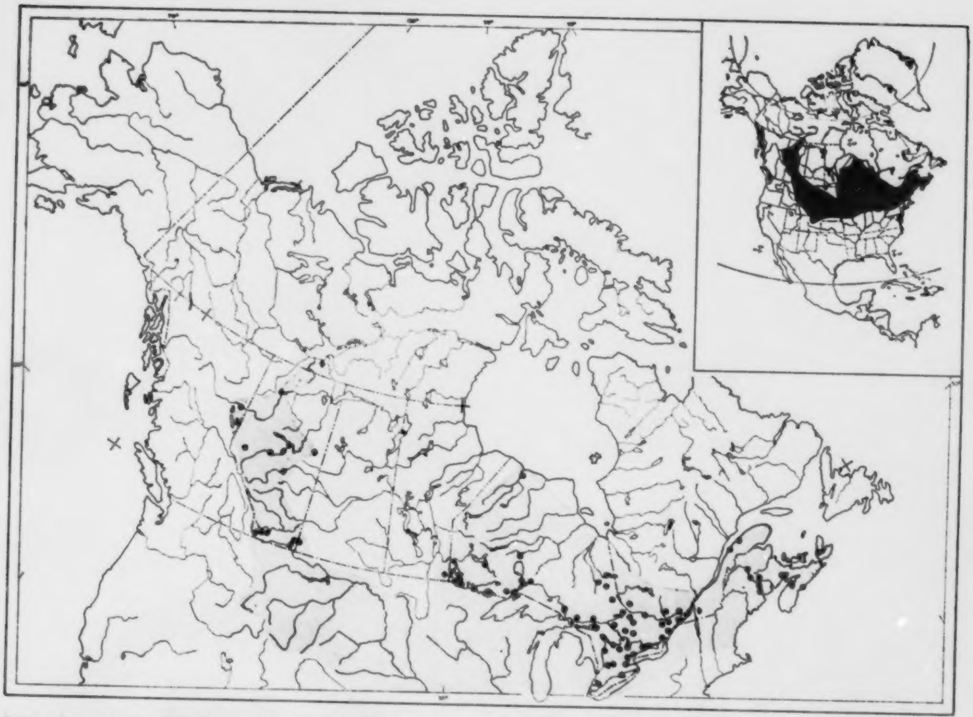
Description Body elongate and tending to be somewhat rounded in cross section, small, average total length about 2 inches (51 mm), body depth 16.0–22.7% of total length. Head moderate, its length 19.5–22.6% of total length; eye large, its diameter 23.0–37.5% of head length; snout comparable to eye diameter, its length 25.0–38.5% of head length; interorbital wide, 33.3–46.1% of head length.



Mouth small, oblique, not reaching a vertical through anterior margin of eye, almost S-shaped when viewed laterally, premaxillaries protractile; pharyngeal teeth usually 0,5–5,0 (sometimes 0,5–3,0 or 0,5–4,0). Fins: dorsal 1, its origin distinctly posterior to pelvic fin origin, rays usually 8(55), sometimes 7(2), or 9(1); caudal distinctly forked, lobes more or less rounded; anal 1, its origin slightly posterior to a vertical dropped from dorsal insertion, rays usually 8(43), sometimes 7(12), but McPhail and Lindsey (1970) said 8 or 9; pelvics moderate, origin in advance of dorsal fin origin, rays 8(38); no pelvic axillary process; pectorals larger than pelvics, rays usually 14(19), but sometimes 13(9), 15(6), or 16(4). Scales cycloid, very small, 70–90 in lateral series; the focus in each scale more nearly centred than in *C. neogaeus*; lateral line not distinct and usually terminating before pelvic fin origin. Peritoneum uniformly black, sometimes dark brown; intestine longer than body, coiled (*see* p. 381). Vertebrae 35(1), 36(8), 37(13), 38(2); Legendre (1969) obtained the following for some Quebec populations: 35(14), 36(33), 37(26), these latter modified for comparison with ours.

Nuptial tubercles, 4 or 5 rows of comblike nuptial organs on the "breast" in front of pectoral origin, and immediately below opercular margin; also a few fine and scattered tubercles on lower surface of head, below cheek.

Colour Back olive to dark brown, sometimes black in deeply stained water; below the lower dark, midlateral band the flanks may be silvery, cream through yellow to brilliant red, depending on sex and proximity to spawning. Fins yellowish when in breeding dress. The brilliant red colouration of males is characteristic through midsummer in most areas. The brilliantly coloured portion of the ventral surface, that is, the red "belly," is bordered above by the lower margin of this black lateral band providing a striking colour contrast. Preserved or immature specimens are usually olive-green on the back, with an interrupted or broken mid-



lateral stripe, flanked on each side by a vaguely defined stripe formed by dots; below each line of dots, an unpigmented area bordered below by the first of two midlateral bands, which commences above the lateral line and above the opercular opening and proceeds posteriorly, terminating on the caudal peduncle; the central and dominant lateral band commences on the snout and extends posteriorly through the eye, cheek, and along the length of the body as a distinct and heavy black band, terminating at the base of the caudal fin, sometimes as a black spot. *See* colour illustrations facing p. 250.

Systematic notes Considerable difficulty in identification is sometimes experienced because of the frequent occurrence in survey collections of *Chrosomus eos* × *C. neogaeus* hybrids, and often in the apparent absence of one of the parental species. The hybrid was reported and discussed in detail by Hubbs and Brown (1929) and more recently by New (1962). A most detailed report was prepared by Legendre (1969) who also showed that the hybrids were fertile and that introgression occurred. Hybrids are often larger than either parent and present a bewildering variety of intestinal track patterns, which have been illustrated by Legendre.

We have not accepted the proposal to merge the North American genus *Chrosomus* in the Old World genus *Phoxinus*, as proposed by Bănărescu (1964) and more recently by the American Fisheries Society (1970), because, in our opinion, this relationship has not been clearly demonstrated. Communication between scientists and the public will not be aided or enhanced by overeager adoption of new names until the old ones have been shown to be inadequate.

Chrosomus erythrogaster, the southern redbelly dace, is a distinct species and does not occur in Canada. (*See also Systematic notes* for *C. neogaeus*.)

Distribution The northern redbelly dace occurs in boggy lakes, creeks, and ponds, from Nova Scotia south to New York and Pennsylvania on the east, west through the Great Lakes drainage (except from Lake Erie in Ohio) to Colorado, and northern British Columbia.

In Canada, it is found in Nova Scotia from Windsor, Hants County, to Lake Ainslie in Cape Breton Island (Livingstone 1953); in New Brunswick in the Saint John River system north to Grand Falls (but not above), in the Meduxnekeag, Digdeguash, Magaguadavic, and Petitcodiac rivers, and has been reported from the Miramichi River. Scott and Crossman (1959) recorded a single specimen, the only record, from the St. Croix River system. First recorded in Prince Edward Island when four specimens were collected in a tributary of the Morell River, King's County (Woronecki 1969). It occurs in Quebec, in Gaspé and through the St. Lawrence River drainage and probably northward to James Bay drainage; throughout Ontario, north to James and Hudson bays; recorded from Goose Creek (55°57′N, 87°22′W), but probably in bog situations throughout the Patricia Portion of Ontario. It has been taken in Manitoba only in the Whiteshell Forest Reserve; reported also from southwestern Saskatchewan in the Cypress Hills. In Alberta, from a few locations in the South Saskatchewan drainage, the Athabasca, and Peace rivers. In British Columbia, only in the northeast, the westerly record from Charlie Lake and its outlet near Dawson Creek (Peace–Mackenzie system); most northerly record is from Fuller Lake in Wood Buffalo Park, N.W.T. (McPhail and Lindsey 1970).

Biology The redbelly dace commences spawning activities in spring or early summer, the exact time depending on latitude and local environment. Precise observations of time and place of spawning in Canadian waters are not readily available. Ripe males and females, taken in mid-June to late June, have been reported for Quebec and Ontario from various areas, and McPhail and Lindsey (1970) reported females containing large eggs caught August 24 in northern Alberta. In Michigan, spawning activities commenced in late May and extended to August, as reported by Cooper (1935) and Hubbs and Cooper (1936), who also presented evidence suggesting that a single female may spawn at least twice in the summer season. Spawning, as reported by Cooper, consisted of the deposition of nonadhesive eggs within masses of filamentous algae. The female, accompanied by one or more males, would dart from one algae mass to another. The males appeared to be attracted to the ripe female by her darting movements. Upon diving into the mass of algae, the spawning pair or group would struggle against the algae, the actual spawning act seeming to take 2–4 seconds. Eggs were deposited and fertilized in each mass. The eggs hatched in 8–10 days at water temperatures of 70°–80° F (21.1°–26.7° C). Hubbs and Cooper considered that those hatching early in the summer probably spawned the following summer, whereas those hatching late in the season probably did not spawn the following summer, but the summer after, i.e., in their third year.

Age determinations using the right opercular bone, were made by Legendre for some Quebec populations. From the growth curves provided, fish grew to the following approximate standard lengths at ages 1–5: age 1, 21 mm; age 2, 1.5 inches (38 mm); age 3, 1.8 inches (46 mm); age 4, 2.1 inches (53 mm); and age 5, 2.3 inches (58 mm). The oldest male he examined was 6 years old, the oldest female, 8; the largest female 2.4 inches (60.9 mm) standard length, the largest male 2.1 inches (53 mm).

This dace seems to prefer the quiet waters of beaver ponds, bog ponds, small lakes, or quiet pool-like expansions of streams, often over a bottom of finely divided brown detritus or silt. In such locations the water is often stained the colour of tea and may be slightly acid. The lethal temperature relations of this and the finescale dace were investigated by Tyler (1966).

Food of the redbelly dace consists mainly of algae such as diatoms and filamentous algae but included in the diet are zooplankton and aquatic insects. Cooper (1936a) observed that redbelly dace 2.0–2.5 inches (51–

64 mm) long would eat smallmouth bass fry 8–9 mm long when held in aquaria.

The redbelly dace probably has a host of predators, such as other fishes, kingfishers, and mergansers, since it is so small and often occurs in large numbers. Presumably, they are consumed by brook trout in our waters but Ricker (1932) found no such evidence although Sibley and Rimsky-Korsakoff (1931) reported this dace in trout stomachs in New York State waters.

Bangham (1955) examined 17 specimens from Rogers and McKim creeks near South Bay, Manitoulin Island, Ont., and found 9 infected with 3 species of larval trematodes and 2 with Gyrodactyloidea. He added that 2 of 10 fish examined from Rogers Creek contained only *Diplostomum* sp.

Bangham and Venard (1946) studied parasites of this species in Algonquin Park lakes and reported 14 of 88 fish were infected. Parasites listed included 2 species of trematodes, 2 species of nematodes and 1 cestode, *Ligula intestinalis*.

Hoffman (1967) listed larval forms of 5 species of trematodes, and the immature adult form of the nematode *Spiroxys* sp., from the northern redbelly dace in North American waters.

Relation to man The tea-coloured, acid waters of eastern Canada, where this colourful little minnow is most abundant, are often the haunt of the brook trout; in such locations, the northern redbelly dace serves as an excellent forage fish, and, being mainly herbivorous, does not compete with the trout for food.

It is rather small for a bait minnow but it is hardy and readily available in the less densely populated portions of Quebec and Ontario, where it is used for bait, often with finescale dace.

Cooper (1935) demonstrated that the redbelly dace could be reared successfully in ponds, but best results were obtained when there was some freshwater flow. He obtained yields of 128,000 fish, or approximately 256 pounds, per acre of water surface in one summer.

Nomenclature

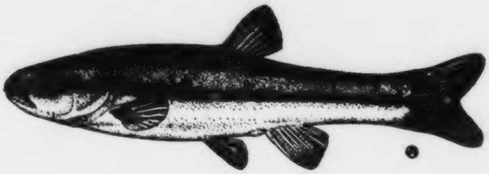
Chrosomus eos — Cope 1862: 523 (type locality Meshoppen Creek, Pa.)
Chrosomus dakotensis — Evermann and Cox 1896: 395
Chrosomus erythrogaster Agassiz — Cox 1896b: 64
Chrosomus erythrogaster Rafinesque — Halkett 1913: 61
— Dymond 1926: 42
— Dymond et al. 1929: 21
Phoxinus eos (Cope) — Bailey et al. 1970: 23

Etymology *Chrosomus* — colour; body; *eos* — sunrise.

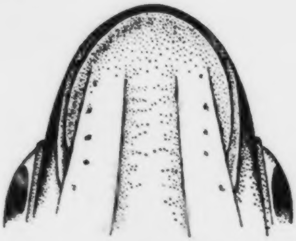
Common names Northern redbelly dace, redbelly dace, red-belly dace, red bellied dace. French common name: *ventre rouge du nord*.

FINESCALE DACE

Chrosomus neogaeus (Cope)



Description Body stout, average length about 3 inches (76 mm), not strongly compressed laterally except latter half of body, maximum body depth occurring about midpoint to tip of pectoral fin, body depth 15.4–22.4% of total length.



Head large, broad, its length 20.0–26.5% of total length; eye moderate, its diameter 21–35% of head length; snout broad, its length 26.3–38.3% of head length; interorbital broad, its width 33.3–45.4% of head length; mouth large, terminal, extending back to below anterior margin of pupil of eye; pharyngeal teeth in two rows, 2,5–4,2 or 2,5–5,2 or 1,5–4,1. Fins: dorsal 1, its origin distinctly posterior to pelvic fin origin, rays usually 8(51), seldom 7(3), or 9(2); caudal with shallow fork, lobes rounded, a distinct round, black spot at caudal base; anal 1, origin under or slightly behind insertion of dorsal fin, rays 8(45), occasionally 7(6), or 9(5); pelvics small, origin distinctly in advance of dorsal fin origin, rays 8(39), seldom 7(2); no pelvic axillary process; pectorals rather fanlike, rays usually 14(24), but may be 15(7), 13(6), 12(2), or 16(2); on spawning males, the first 4 or 5 rays are darkly pigmented, thickened, and strengthened, becoming almost like spines in their degree of rigidity, and appearing as if deformed from fin clipping at a point about three-quarters along length of fin; on the same individuals, nuptial tubercles are developed on "breast" and flanking anal fin base. Scales cycloid, small, 63–85 in lateral series, focus eccentric; lateral line incomplete, extending from behind dorsal part of gill cover, quickly curving downward to follow ventral margin of lateral band, terminating usually above pelvic fin origin. Peritoneum uniformly black; intestine short, a single S curve. Vertebrae 37–39.

Nuptial tubercles in 4 or 5 rows of comblike structures on breast in front of pectoral fin origin and below posteroventral margin of operculum; 4 or 5 rows of tubercles on scales above the base of the anal fin and extending posteriorly almost to the beginning of the lower lobe of the caudal fin.

Colour Back dark brown, almost black in dark peat-stained water; the darkly pigmented back extends downwards about halfway between midline of back and free dorsal edge of operculum, this black cap on the back ending sharply; below this, a sparsely pigmented area, a lateral stripe, olive-green or gold in life, immediately above the densely pigmented and distinct lateral band, which commences on snout (lips pigmented but chin immaculate), proceeds through eye, across opercle, along length of body, and terminates in a distinct caudal spot. On breeding males, the whole ventral surface, from lower margin of the lateral band on each side, flushed with chrome yellow, at times strikingly intense, to brilliant red. Subadults and nonbreeding adults are silvery white below. Fins usually have an amber or light yellow tint, the rays pigmented, more intensely at spawning time. *See* colour illustrations facing p. 250.

Systematic notes Morphological and anatomical variations of the finescale dace throughout its range have not been examined, and to our knowledge, geographic races have not been proposed.

Considerable discussion, however, has arisen concerning the most appropriate generic placement.

Most North American workers followed Bailey's (1951) proposal to merge the genus *Pfrille* with *Chrosomus*. Some favour placement of *neogaeus* in the Old World genus *Phoxinus*, a view that was expressed by Bănărescu (1964) and has gained partial favour with some, notably McPhail and Lindsey (1970) who reviewed this question. But, the casual placement of *neogaeus* in *Phoxinus* proves nothing, since without adequate documentation (one might almost say, without the application of the usual scientific procedures) we are no wiser than before. Compilers and biogeographers, being unaware of this weakness, will not be better served.

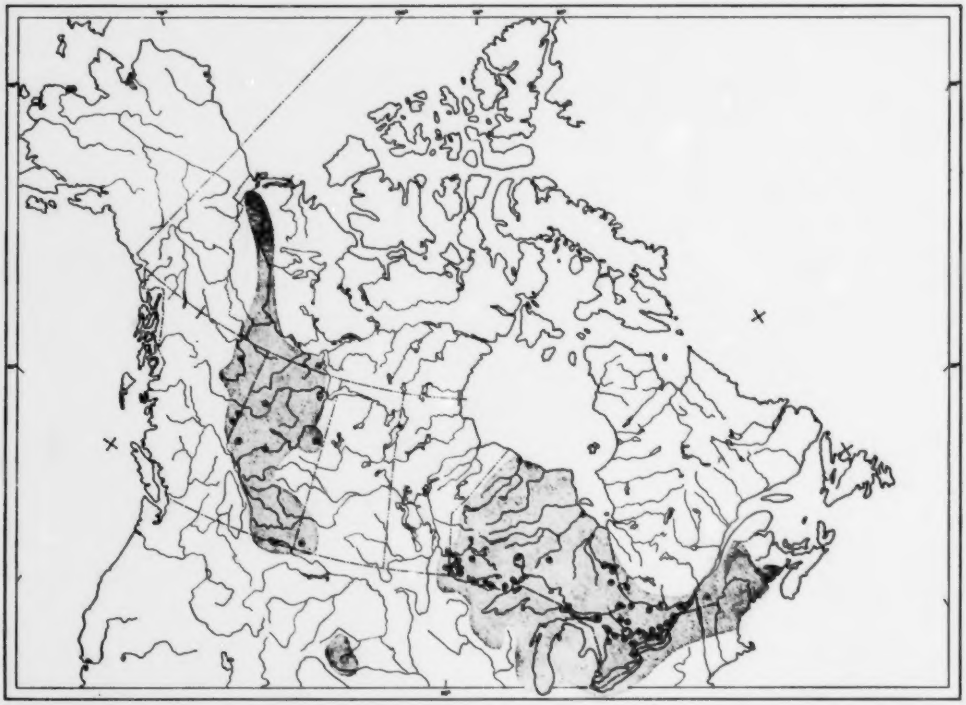
Whatever the decision, the closeness of the relationship of *Chrosomus eos* and *neogaeus* can surely not be denied. Most field biologists experience considerable difficulty in distinguishing the two species, especially since they hybridize rather freely, producing fertile hybrids, according to Legendre (1969), who also noted that both species carry 50 diploid chromosomes (as do *Semotilus margarita* and *Couesius plumbeus*). In fact, Legendre considered it reasonable to transfer *margarita* from the genus *Semotilus* to *Chrosomus*. (*See also Systematic notes* for *C. eos*.)

Distribution The finescale dace occurs in bog ponds, streams, and lakes from New Brunswick, Maine, and New Hampshire on the east, through southern Quebec and northern New York State, north of the lower Great Lakes to Michigan, and northwest to the Arctic Circle in the Mackenzie River system. Isolated populations reported in South Dakota, Nebraska, Colorado, and Wyoming (Bailey and Allum 1962).

In Canada, this dace is reported from scattered locations in New Brunswick, through southern Quebec including lower Gaspé, throughout Ontario (excepting southwestern Ontario), north to Hudson Bay; in Manitoba from Brereton Lake, Telford Pond, and Rennie River, all in southern Manitoba; in Saskatchewan from the Cypress Hills region in a tributary to Frenchman River of the Missouri drainage, and also in a tributary of the South Saskatchewan River; in Alberta in tributaries of the Milk River in the south, and from the vicinity of West Pierre Greys Lake, Horne Lake, and East Hawk Hills Lake. It occurs in British Columbia in the Mackenzie River system (Fort Nelson River and One Island Lake) and downstream in the Mackenzie River system of the Northwest Territories to the Arctic Circle. McPhail and Lindsey (1970) specified that it did not occur in the upper Liard or Peace River basins.

It is absent from Newfoundland, Nova Scotia, and Prince Edward Island.

Biology Spawning presumably occurs in the spring, probably in June in northern Ontario. Dymond (1926) reported taking females with nearly ripe eggs on June 24, 1924. We also have at hand field sketches by T. M. Shortt of brightly coloured males taken on Albany Island, James Bay, on June 15, 1942. But details such as place of spawning, number of eggs, spawning behaviour, and so forth, have not been documented, or at least not published. Presumably the modified pectoral fins of the male in spawning condition are important in some phase of the spawning procedure. The rays of the pectoral fins, especially the first five or six, are thickened and stiffened and develop a swelling on each ray about one-quarter of the length of the ray from the tip. The outer part of the fin curls



upward, the whole fin giving the impression that it was deformed by fin clipping. The fins also stand out stiffly from the body and cannot be readily depressed.

Preferred habitats seem to be the cool bog lakes, streams, and some larger lakes of the central and northern part of the continent. It seems most often to be found in stained, boggy waters. Dymond (1926) noted that *p*H readings of two such lakes near Lake Nipigon showed them to be neutral or slightly acid (6.9–7.0).

The finescale dace is usually found in association with *C. eos*, *Semotilus margarita*, and *Culaea inconstans*. It seems to hybridize readily with *C. eos*, the resulting hybrids are fertile (Legendre 1969); it is probable that introgression is common. Legendre gave a few data on the growth of the hybrids but not for this parent species.

The few stomachs that have been examined suggest that insects form a major part of the summer diet, but crustaceans and plankton are also consumed. In the absence of information, further speculation seems pointless.

There are apparently no records in Canadian literature of the parasites of this dace.

Hoffman (1967) listed the protozoans *Myxosoma parellipticoides*, *M. pfrille*, and *Thelohanellus notatus*, and the larval forms of the trematodes *Echinochasmus donaldsoni* and *Uvulifer ambloplitis* from the finescale dace in North American waters.

Relation to man The role of the finescale dace in the ecology of our aquatic communities is not known; indeed we know next to nothing about the life history of the species.

Because of its size, hardiness, and availability, it is used as a bait minnow in parts of Quebec and northern Ontario, most often sold under the name "chub."

Nomenclature

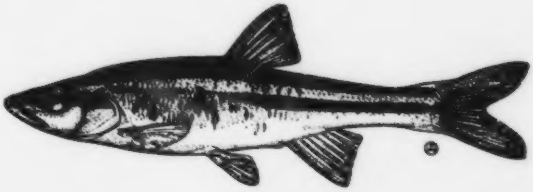
Phoxinus neogaeus — Cope 1869: 375 (type locality New Hudson, Mich.)
Leuciscus neogaeus (Cope) — Jordan and Evermann 1896–1900: 240
Pfrille neogaeus Cope — Hubbs 1926: 34
Pfrille neogaea (Cope) — Jordan, Evermann, and Clark 1930: 121
Chrosomus neogaeus — Legendre 1953: 246
— Hubbs and Lagler 1958: 80
Phoxinus neogaeus Cope — Bailey et al. 1970: 23

Etymology *Chrosomus* — colour; body; *neogaeus* — new; world.

Common names Finescale dace, fine-scale dace, fine-scale minnow, bronze minnow. French common name: *ventre citron.*

REDSIDE DACE

Clinostomus elongatus (Kirtland)



Description Body slender, elongate, averaging about 3 inches (76 mm) long, distinctly compressed laterally, the greatest depth 17.1–20.0% of total length. Head pointed, triangular, its length 21.8–23.3% of total length; eye moderate, its diameter 23.6–29.6% of head length; snout sharply pointed and long, its length 32.0–42.8% of head length; interorbital width somewhat greater than eye diameter, 26.6–33.3% of head length; mouth very large, terminal, lower jaw distinctly projecting, gape extending to below anterior half of eye; pharyngeal teeth well developed, slightly hooked, usually 2,5–4,2 (occasionally 1,4–3,1). Fins: usually transparent; dorsal 1, its origin clearly posterior to pelvic fin origin, rays usually 8(21), rarely 7(1); caudal distinctly forked; anal 1, rays usually 9(17), occasionally 8(4), rarely 10(1); pelvics originating in advance of dorsal fin origin, rays always 8; pectorals elongate, tips reaching origin of pelvics, rays 14–16. Schwartz and Norvell (1958) noted that pectorals of males are longer than those of females. Scales cycloid, persistent, 63–70 in lateral line; lateral line complete, slightly decurved. Peritoneum silvery, speckled. Vertebrae 38–41, usually 40 or 41.

Nuptial tubercles on breeding males small or minute and distributed over nearly all of body, but larger on dorsal surface of head, body, and pectoral fins; females also develop tubercles but these are smaller and not so widely distributed as on males.

Colour Adult redside dace are usually highly colourful, with iridescent reflections of blue, green, purple, and violet; back usually dark green or blue-green, below which is a thin, golden stripe along sides, level with the eye and extending posteriorly to caudal peduncle. Below the gold stripe is an orange or red band, extending from opercle or gill cover to below dorsal fin or beyond. Preserved specimens dark on back, below this on each side is a narrow light stripe and beneath the light band is a dark lateral band, vague in its beginnings but usually originating below dorsal fin and continuing posteriorly to caudal peduncle. The sides are usually sprinkled with specialized darkened scales and rather distinct spots of pigment.

Distribution The redside dace has a limited distribution in North America. It occurs in the United States in the upper Mississippi drainage system from New York State, south to Kentucky, and west to Wisconsin, Iowa, and Minnesota (Moore 1968).

In Canada it is found only in clear streams flowing into western Lake Ontario, in the counties of Brant, Bruce, Halton, Ontario, Peel, Wentworth, and York.

Biology No studies of this species in Ontario waters have apparently been made, all the more unfortunate since the redside dace is much less common now than 30 years ago.

Spawning in northern New York State was recorded by Koster (1939), who observed spawning fish in a stream south of Ithaca in 1936. Spawning was observed May 22, 24, 25, and 26, close to the bottom, and usually in or near the gravelly nests of creek chub. The lowest temperature at which spawning was observed was 65° F (18° C). In one closely studied area, Koster noted that the adults foraged in an upstream pool and moved downstream to a gravel area to spawn. With the approach of spawning time, males tended to defend small, poorly defined, territories, but abandoned these when spawning actually commenced. During spawning, the males would congregate in dense schools downstream from creek chub nests, the females positioned on the lateral and posterior margins of a school. Spawning would commence when a female moved upstream toward the creek chub nest, to be joined on the way by two or more males. Spawning occurred in the pit of the creek chub nest, often when the male creek chub was present. On a number of occasions, the spawning act was repeated four to six times within 1 minute, but Koster noted that usually several minutes elapsed between matings. Koster described the movements and general behaviour of the prespawning and spawning dace in considerable detail.

The number of eggs per female varied from 409 to 1526 by direct count on 15 females. When water hardened, eggs measured 1.2–2.4 mm in diameter and were nonadhesive.

Koster made age determinations from scales, although he considered the scales difficult to read. *See also* details on scale reading by Schwartz and Norvell (1958). Koster concluded that spawning first occurred in the third year; the oldest specimens found were in their fourth year. The largest specimens seen by Koster had total lengths of 3.5 inches (89 mm) for males and 3.8 inches (97.5 mm) for females. The largest Ontario specimens are about 4 inches (100 mm) total length. Koster presented the following standard lengths (in millimeters) for May-caught specimens:

Age	M	F
1	38.0 ± 2.5	37.3 ± 2.8
2	55.6 ± 2.9	57.0 ± 2.7
3	61.7 ± 3.4	69.1 ± 3.2

Redside dace prefer clear, cool, flowing water with gravel or stoney bottom. According to Trautman (1957) they are apparently quite sensitive to turbidity.

Food consists mainly (95%) of insects. Terrestrial insects make up the bulk of ingested material, constituting 76.9% of all food eaten. Many of these are caught in flight by leaping dace. The large mouth is ideally suited to this kind of feeding. The more common insects were Diptera (flies), Ephemeroptera (mayflies), and Odonata (dragonflies). Spiders are also eaten (Schwartz and Norvell 1958).

There are no reports of parasitic infestation of the redside dace in Ontario waters. Hoffman (1967) listed only two parasites, the trematodes *Dactylogyrus extensus* and *Neodactylogyrus confusus*, from the species in North American waters.

Relation to man The redside dace is of little direct importance to man because of limited distribution. However, it is of biological interest because of its unique adaptations for feeding on insects, such as its large mouth and jumping ability. Its present restricted Canadian distribution and sensitivity to turbidity suggest that this dace will become increasingly rare.

Nomenclature

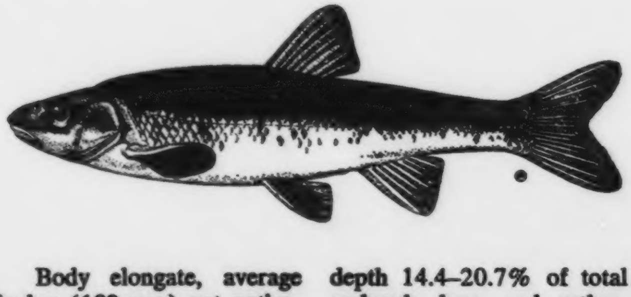
Luxilus elongatus — Kirtland 1838: 193 (type locality Lake Erie, near Cleveland, and Mahoning River, Ohio)
Leuciscus elongatus (Kirtland) — Jordan and Evermann 1896–1900: 240
Richardsonius elongatus (Kirtland) — Bailey 1951: 191
Gila elongata (Kirtland) — Bailey 1956: 331
Clinostomus elongatus — Hubbs and Lagler 1958: 80

Etymology *Clinostomus* — to incline; mouth; *elongatus* — lengthened.

Common names Redside dace, red-sided shiner. French common name: *méné long*.

LAKE CHUB

Couesius plumbeus (Agassiz)



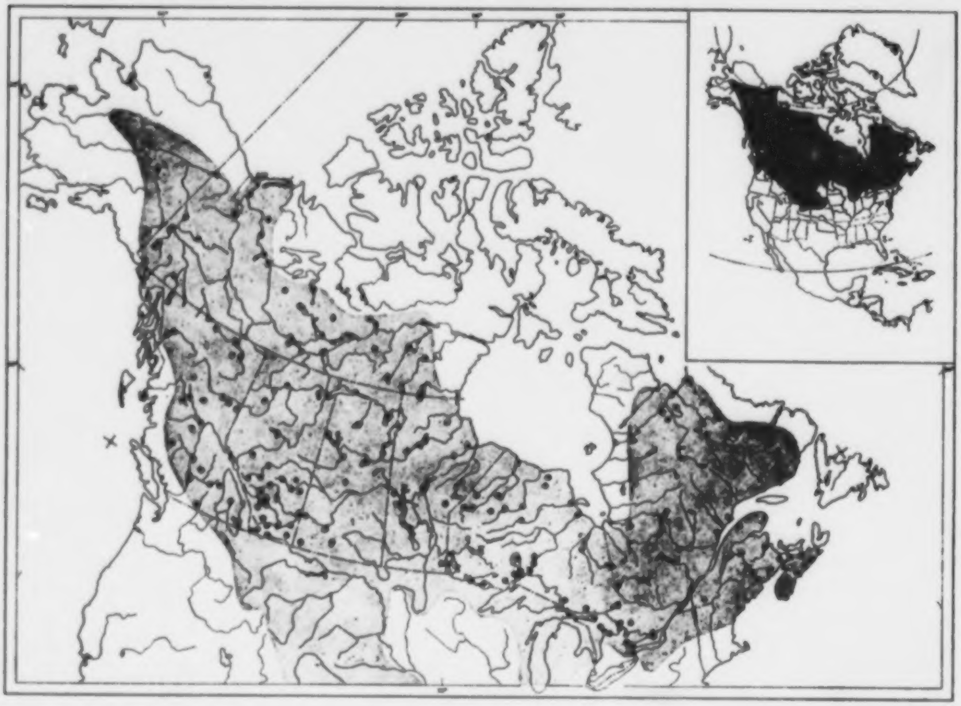
Description Body elongate, average length about 4 inches (102 mm) not noticeably compressed laterally, greatest body depth 14.4–20.7% of total length; caudal peduncle long and rather slender. Head rather short, its length 18.8–22.2% of total length; eye size variable, its diameter 20.4–33.3% of head length; snout bluntly rounded, its length 26.6–40.0% of head length, usually projecting slightly beyond upper lip, particularly in eastern Canadian populations; interorbital width 33.3–42.8% of head length; mouth moderately large, upper jaw almost reaching anterior margin of eye, a well-developed, threadlike barbel at each corner of the mouth, its base affixed very slightly in advance of end of maxillary, but the tip appearing at end of maxillary; pharyngeal teeth usually 2,4–4,2, but variable, 2,4–4,0, 2,5–4.2 (McPhail and Lindsey 1970, gave extremes of 0,4–4,0 and 2,5–4,2), flattened and hooked. Fins: dorsal 1, its origin slightly posterior to pelvic fin origin; Hubbs (1942) noted that dorsal fin origin was sex dependent, at least in part, and McPhail and Lindsey suggested that origin was age dependent, but the relative positions of dorsal and pelvic fin origins seem also to be geographically variable, rays consistently 8(87); caudal moderately well forked, lobes rounded; anal 1, origin below posterior free margin of depressed dorsal fin, rays usually 8(83), seldom 9(3), or 7(1); pelvics well developed, origin usually slightly in advance of dorsal fin origin, rays usually 8(56), seldom 7(3), or 9(1); pelvic axillary process not developed or, at best, a simple ridge; pectorals broad, well developed, rays usually 15(15) or 16(28), sometimes 13(2), 14(4), 17(8), or 18(3). Scales cycloid, persistent, somewhat elongate, isolated darkened scales common on eastern and northeastern specimens, less so in northwest; lateral line complete, total number of pored scales usually given as 53–79 but 58 samples yielded range of 56–69 and McPhail and Lindsey had 58–65 in their area. Peritoneum silvery, speckled; intestine short, proportional length of digestive tract 0.9–1.2 in total length (Dymond 1926). Vertebrae usually 40 or 41, total range 39–43. McPhail and Lindsey said 39–44.

Nuptial tubercles small but well developed on males, slightly less so on females, on top of head, scattered on sides of head, around orbits, scattered lightly on back from nape to dorsal origin, well developed on dorsal surface of pectoral rays, and well developed on scales on breast from around pectoral bases forward to cleithrum on eastern Canada specimens as well as those in northwest. A few tubercles developed on first two rays of pelvic fin.

Colour The overall general colouration is leaden silvery (from which the scientific name is derived). The colour of the back may be pale olive to olive-brown, brown, dark brown, or almost black, becoming leaden silvery on the sides and silvery white below. The lower sides and belly are often sprinkled with dark pigment. Specialized, darkened scales, comparable to those of the pearl dace, are often present on the sides. The midlateral band is not usually evident in life but is pronounced in young fish to lengths of about 2 inches (51 mm), and in eastern Canadian populations may persist throughout adult life. McPhail and Lindsey (1970) stated that it is indistinct and only on posterior half of the body of adults.

Bright colours are less flamboyantly displayed than in *Chrosomus* or *Semotilus margarita*, except for dashes of brilliant red or red-orange on breeding males, at the bases of the pectoral fin, sometimes also at pelvic fin bases and at the corners of the mouth. The presence and amount of colour seems to vary with region. McPhail and Lindsey specified that colour was absent on breeding males of the Pacific form. On the other hand, Dymond (1926) found Lake Nipigon specimens to be highly coloured with red not only at bases of paired fins but also on snout between eye and maxillary and below the upper posterior margin of opercle at origin of lateral line. Richardson (1944) made similar observations in Quebec, but, in an earlier account (Richardson 1935) he reported that no marked sexual differences were apparent among spawning adults taken at Lac Saugay, Que., and that both sexes were coloured.

Systematic notes For many years *Couesius plumbeus* was considered by many authors to be represented throughout its wide



range by three subspecies, all of which occurred in Canada: *C. p. plumbeus* of eastern North America, the Great Lakes, and the northwest; *C. p. dissimilis* of the upper peninsula of Michigan and west on either side of the international boundary to the eastern foothills of the Rocky Mountains; and *C. p. greeni* of the Pacific slope. But with the merging of the genus *Couesius* in *Hybopsis*, which was proposed by Bailey (1951), the name *dissimilis* became unavailable since it was preoccupied in *Hybopsis*. Subspecies designations for *Couesius plumbeus* have been questioned and were thoroughly discussed by Lindsey (1956). At present, the status of subspecies for *C. plumbeus* are in doubt and are not employed here, which is not to deny the existence of many differences between populations but to indicate that the application of names implies a degree of understanding that does not exist.

The proposed merging of *Couesius* with *Hybopsis* was accepted by many workers but not by all. It was accepted, however, and published by the American Fisheries Society in its Special Publication no. 2 (Bailey et al. 1960). But the genus *Couesius* was employed in the 1970 revision of the names list. *See* McPhail and Lindsey (1970) for a discussion of the generic placement of *Couesius* and *Platygobio* in *Hybopsis*.

A comprehensive study of the systematics of *Couesius plumbeus* in Saskatchewan was recently completed by J. H. Brown and U. T. Hammer, University of Saskatchewan, but has not yet been published.

Distribution The lake chub occurs widely throughout Canada and in scattered localities in the northern United States, from northern New England to New York, in Michigan, relict populations in Iowa, scattered distribution in Wisconsin, Minnesota, the Dakotas, Montana, Wyoming, Colorado, and in Idaho south to Lake Pend Oreille.

In Canada, the species is found in streams, rivers and lakes throughout the mainland of Nova Scotia from the Moser River, Halifax County, to Bear River, Annapolis County. It is wide ranging throughout New Brunswick, particularly in the northern part. It has been reported from many parts of Labrador by Backus (1951) and others, in Hamilton Inlet basin and Grand Lake system, more often in streams and lake-like expansions of rivers. It is widely distributed in Quebec, north to Ungava where it is known to be widely distributed, east to about Gethsemani, and in many of the streams, rivers, and lakes of the Ungava Bay drainage (Power and Oliver 1961; Harper 1961), sometimes downstream to the head of tide, and it was reported from Indian House Lake, far upstream in the George River system by Legendre and Rousseau (1949); on both sides of the St. Lawrence, including Gaspé, on the north shore east to about Gethsemani, uncommon in the Lac St. Pierre–Lac St. François region of the upper St. Lawrence system, occurring only in tributary streams. The lake chub occurs throughout Ontario in streams and lakes, including the Great Lakes (except in lakes Erie and St. Clair), north to Hudson Bay.

In Manitoba, Saskatchewan, and Alberta it is common in many streams and rivers in the southern parts and in lakes in the north. In Manitoba it occurs widely, and Keleher and Kooyman (1957) recorded it from many localities north to South Knife Lake at 58°10′N, 96°28′W, although we now know it ranges into the Northwest Territories. In Saskatchewan and Alberta it occurs widely from the Cypress Hills region in the south to Lake Athabasca in the north, and northward into the territories (Henderson and Peter 1969; McPhail and Lindsey 1970). In British Columbia, it ranges widely throughout the province, in the Columbia and Fraser River systems, the Skeena, the Peace, the Liard (Mackenzie system), and the Yukon. In the Northwest Territories it ranges from Chesterfield Inlet tributaries and Nueltin Lake, westward through the major watersheds of the territories, downstream in the Yukon River in Alaska at least to Nulato (McPhail and Lindsey 1970).

Biology Despite the wide distribution of this species throughout Canada, relatively few serious studies of its biology have been conducted, and fewer still have been published. (Geen, unpublished MS; Brown, unpublished MS.)

The data available are from widely scattered regions and, hence, generalizations could be misleading. A species that spawns in April in Lake Ontario might not reproduce until July or August in the Northwest Territories.

The lake chub usually undergoes a spawning migration from lakes to tributary streams early in the spring. In the Great Lakes, this takes place about the same time as, or earlier than, the smelt runs (usually April). In Lake Nipigon, spawning is said to occur in June (Dymond 1926). Richardson (1935) caught many ripe females and a few males in a tributary stream to Lac Saugay, Que., early in June when water temperature in the stream was 57° F (14° C) and in the lake 66.2° F (19° C). At Lac la Ronge, Sask., they were observed spawning among large rocks in the shallows of the Montreal River in middle or late May, without building a nest or guarding eggs, according to McPhail and Lindsey (1970) who obtained this information from the field observations of J. H. Brown, University of Saskatchewan. McPhail and Lindsey also noted that spawning commenced in some lakes of the Cariboo District of central British Columbia in late May or early June. During surveys on the Barren Grounds of the Northwest Territories in 1959, well-tuberculated ripe males and females were caught as late as August. The eggs are yellowish in colour and Richardson (1935) estimated 500 eggs in a female 2.8 inches (70 mm) long, but additional details such as time to hatching and rate of development are apparently not available.

Details of growths are also unavailable but Geen's (1955) study in central British Columbia indicated that fish matured in their third or fourth year and probably seldom survived beyond 5 years, and that females grew faster and lived longer than males. Richardson (1935) also observed large numbers of dead lake chub, most of which had spawned, in a stream in southwestern Quebec, suggesting that postspawning mortalities occur.

The lake chub is a large minnow, commonly reaching sizes in excess of 4 inches (102 mm). The largest specimens we examined were from Lake Mattagami, Nottaway River drainage, Que., and measured 227 mm in total length, or over 8.9 inches. In a sample of seven spent females provided by Vianney Legendre, six were about 8 inches (over 200 mm) in total length. All were caught by gillnets from August 13 to 31, 1963. Sizes to 6.25 inches (158 mm) were not uncommon in the Severn River (Dymond and Scott 1941) and Dymond (1926) gave the length of the largest specimen in Lake Nipigon as 5.25 inches (133 mm) (probably standard length). Large minnows of this size are not usually captured easily in shore seines and it seems worth noting that the large fish from Mattagami Lake were taken by gillnet and the 6.25-inch specimens from the Severn River were caught by seining at night. Large specimens may be more common than the present sampling methods would suggest.

Appraisals of habitat preference are, to date, dependent on capture, and conclusions based on these captures are biased since most of the available observations relate to fish migrating into streams for spawning. The lake chub seems to resort to lakes, whenever these are available, and move into the deeper parts of lakes during summer, or so gillnet capture would indicate. In the northern parts of the range, if large lakes are not available, they can successfully live in large rivers such as the Severn, the Mackenzie, and the Yukon and are, therefore, highly adaptable.

Extensive food studies have not been made but stomach analysis for some Ontario populations indicates that chironomid larvae and other aquatic insect larvae form the major part of the diet with small amounts of cladocerans and algae. Studies in British Columbia, reported by McPhail and Lindsey, showed that terrestrial and aquatic insects, zooplankton and algae were the main food items, and some large chub had eaten small fishes. It was classified as a sight feeder by Davis and Miller (1967) because it has large optic lobes and only a moderate number of taste buds.

Predation on lake chub by larger predaceous fishes, such as lake trout, burbot, or walleye is probably considerable but direct evidence is meagre. Northern pike were observed preying upon lake chub in Northwest Territory lakes in July, 1959. Predation on lake chub by mergansers and particularly by kingfishers was documented by White (1953, 1957) for the Maritime Provinces.

The lake chub seems to harbour a rather rich parasite fauna. Bangham (1955) examined lake chub from Lake Huron, Ont., and recorded the larval form of two trematodes, *Diplostomulum* sp. and *Posthodiplostomum minimum*, the adult form of nematode, *Rhabdochona* sp., and an acanthocephalan *Echinorhynchus salmonis*. Bangham and Adams (1954) examined 161 specimens of lake chub from three localities in the Columbia River drainage of British Columbia and from two areas of the Fraser River drainage. They found 160 fish infected, and recorded 18 species of parasites, over one-half of which were larval or encysted forms. They noted that in many cases, the fish acted as an intermediate host, final development taking place in fish-eating birds and in other fishes.

In a review of the parasites reported for the species in North America, Hoffman (1967) listed one protozoan, seven species of trematodes, four cestodes, two nematodes, two acanthocephalans, glochidia, and one crustacean, *Ergasilus caeruleus*.

Relation to man The role of the lake chub in the bioeconomy of our aquatic environments is really not known. Its extremely wide distribution in Canadian fresh waters, when considered with what we know of its food habits, suggests that it is a forage fish of considerable importance.

Lake chub have been tested by a cold-smoke process by the Fisheries Research Board of Canada, and the resulting product considered satisfactory (Lantz 1962).

In the Lake Superior drainage of Ontario, Allin (1953) reported that lake chub (designated in this instance by Allin as *C. p. dissimilis*) interferes with brook trout angling, particularly in Nishin Lake, for "it is almost impossible to make a cast without catching one of these minnows."

It is frequently caught by sportsmen stream fishing for smelt in Lake Ontario and Lake Huron drainages, is usually unrecognized, and is mistakenly taken and eaten for smelt. In the same regions, the spring-spawning runs are fished by bait dealers, usually in early April, and the chub are held for sale as walleye bait. Allin (1953) noted that it was also used for live bait in lake trout fishing in the vicinity of Rossport, Lake Superior.

Nomenclature

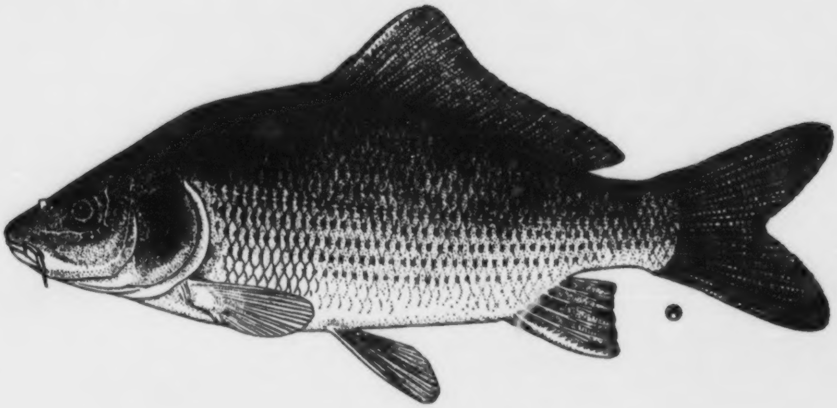
Gobio plumbeus — Agassiz 1850: 366 (type locality Lake Superior)
Leuciscus cephalus — Perley 1852: 194
Nocomis milneri — Jordan 1877a: 64
Couesius greeni — Jordan 1893: 313
Couesius prosthemius Cope — Cox 1896b: 65
Ceratichthys prosthemius — Cox 1896b: 65
Ceratichthys Plumbeus Günther — Cox 1899: 146
Couesius plumbeus (Agassiz) — Scott and Crossman 1959: 20
Hybopsis plumbea — Bailey et al. 1960: 14
Couesius plumbeus — Bailey et al. 1970: 19

Etymology *Couesius* — after Dr E. Coues, American ornithologist, collector of type specimens; *plumbeus* — lead coloured.

Common names Lake chub, northern chub, lake northern chub, creek chub, chub minnow, plumbeus minnow, Moose Lake minnow, bottlefish. French common name: *méné de lac*.

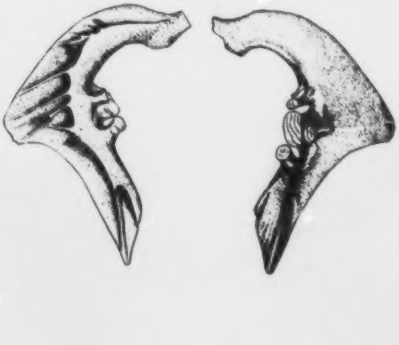
CARP

Cyprinus carpio Linnaeus



Description Body robust, compressed laterally, usually 15–18 inches (381–457 mm) long, body depth 25.8–32.8% of total length. Head triangular, its length 23.3–27.2% of total length; eye small, its diameter 17.7–23.3% of head length; snout long, 33.3–42.8% of head length; interorbital 31.5–42.8% of head length; mouth of moderate size, toothless, upper jaw slightly protruding. Two pairs of barbels about the mouth, posterior pair at the corners of the mouth most conspicuous; pharyngeal teeth distinctly molarlike 1,1,3–3,1,1. Gill rakers 21–27. Fins: all fins opaque; dorsal 1, long, of 1 stout, toothed spine and usually 18–20 soft rays; caudal forked; anal 1, of 1 stout heavy spine with serrations on trailing edge, 5 branched rays; pelvics thoracic, originating beneath origin of dorsal fin, of 8 or 9 rays; pectorals of 15 or 16 rays, occasionally 14–17. Scales cycloid, large, thick, 35–39 in lateral line; occasionally scales enlarged and scattered (mirror carp), or absent (leather carp); lateral line complete. Vertebrae 35 or 36.

Nuptial tubercles fine and scattered.



Colour Colouration variable; adults usually olive-green on the back, becoming yellowish on the belly. Lower half of the caudal fin and the anal fin often with reddish hue, with stronger colouration on large adults.

Systematic notes For information on hybridization with goldfish, *see Systematic notes* for goldfish, p. 389.

Distribution The carp was indigenous to temperate portions of Asia before the Christian era and also occurred naturally in Europe. It was introduced into England during the reign of Henry VIII and, because of its suitability for pond culture and its popularity as a food fish, it was introduced into North America. DeKay (1842) quoted a letter from Capt. Henry Robinson, of New York, stating that in 1831 and 1832 he brought 6 or 7 dozen carp from France and put them into his private pond near the village of Newburgh, N.Y. He further stated that he had released carp into the Hudson River after rearing them in his pond. Some doubt exists as to whether these fish were *Cyprinus carpio*, goldfish, or hybrids (McCrimmon 1968). Introductions into American waters by the U.S. Fish Commission followed and, after initial failures to establish the fish, success was achieved in 1877. Distribution by the United States Government was made from Washington, on request from applicants in the United States and Canada, until 1896 when there was no need for further distribution of parent stock (Smallwood and Smallwood 1929).

In Canada, carp are now widely distributed through Quebec, Ontario, Manitoba, Saskatchewan, and British Columbia. They are known to occur in brackish waters of the Atlantic coast.

An attempt was made to establish carp in New Brunswick in 1880 (McCrimmon 1968), but this was apparently unsuccessful and it is unknown from this area (Scott and Crossman 1959) or from Newfoundland (Scott and Crossman 1964). There are no records from Prince Edward Island or Nova Scotia.

The easternmost limit of range is Rivière Ouelle, below Quebec City, reported in 1960. McCrimmon (1968) stated that carp were present in the St. Lawrence basin as early as 1910.

In 1880, carp were brought into Ontario by Messrs S. and B. F. Reesor, and established in a pond in Cedar Grove area, near Markham. In the upper branches of the Holland River, several mill ponds were stocked (MacKay 1963). In 1896 a dam broke at Dykes Pond, Newmarket, and it is assumed that carp escaped into public waters in Ontario in this way. MacKay (1963) suggested, however, that the species could have entered the Great Lakes from other sources. Dymond (1955) stated carp are widely but not universally distributed throughout southern Ontario, including shallow bays of lakes Ontario, Erie, and Huron, and are spreading northward wherever progress is not barred by waterfalls, and other obstacles.

In 1889, a shipment was received from the United States and planted in a mill pond near Rapid City, and in Lake Minnewawa near Glenboro, southern Manitoba, introducing the species into water tributary to the Assiniboine system at Rapid City. This planting also appears to have met with no success for, in 1943, Hinks recorded the first record of carp in Manitoba in 1938, in the Red River at Lockport, 49 years after the 1889 planting, and at a site well removed from Rapid City. After 1938, carp spread through the Nelson River drainage and are now caught in commercial fishing operations in the southern part of Lake Winnipeg. They also occur in many other inland waters in this province, including lakes Manitoba, Winnipegosis, Dauphin, Playgreen, Cedar, and Split. Split Lake is the most northerly record of carp in North America (McCrimmon 1968).

Atton (1959) stated that in 1885, 100 carp were received from St. Paul, Minn., and planted in ponds at Springfield, Portage la Prairie, and Minnedosa, Manitoba, and a further supply received and planted the following year. These attempts to establish populations were apparently not successful.

Carp were recorded in 1953 from Kamsack, Sask., in the Assiniboine River. The earliest acceptable record of carp there is from the Frenchman Creek in the southwestern corner of the province.

Atton (1959) stated populations of carp existed in the Milk River (Missouri system) in Alberta since 1921, but these populations did not spread because of the lack of permanent waters. McCrimmon (1968), however, noted that there appears to be no evidence of carp in the waters of Alberta. Further, he observed there appears to be no evidence of the species from the area of Manitoba and Ontario between Lake Winnipeg and Lake Superior.

Population of carp as a result of introduction into a pond on Vancouver Island, B.C., possibly around 1897, existed until recent years. The populations now present in British Columbia, in the Columbia and Fraser River systems, probably result from a northward spread of carp established in the Columbia River system in the State of Washington during the 1880's, moving through the Okanagan watershed (first recorded in Okanagan Lake in 1917), thence through creeks or irrigation ditches to Fraser valley (*see* Carl et al. 1967, for detailed distribution in British Columbia).

McCrimmon (1968) gave detailed accounts of introduction and distribution of carp in Canada.

Biology Carp spawn in the spring and early summer. As the waters warm, adults move into weedy or grassy shallows, at first gathering in rather large numbers, often near the surface where they are readily visible to the alert observer. As warming trends continue, the potential spawners commence to form smaller groups of 1–3 females and 2 or 3–15 males. Spawning does not commence in earnest until temperatures reach a level of at least 62.6° F (17° C) and may continue for several weeks. Spawning activities begin to decline when temperatures reach 78.8° F (26° C) and cease altogether at 82.4° F (28° C) (Swee and McCrimmon 1966; McCrimmon 1968).

In Lake St. Lawrence, Swee and McCrimmon observed that spawning may be interrupted if cooler weather prevails and the temperature drops below 62.6° F (17° C), but will recommence when the water warms up again. Spawning is usually extended when temperatures permit and in the Great Lakes region may extend from May to August (Swee and McCrimmon 1966). On a warm sunny morning, spawning carp may be seen and heard swimming about, splashing and thrashing in the shallow water, their backs sometimes completely exposed. Usually a female will be accompanied by 2 or 3 males and the noise and splashing is made by fish of 5 pounds or more racing about madly in shallow water. Many an early morning, the bass fisherman, casting into weedy shallows, has been startled by the sudden arrival of one or more groups of spawning carp.

It is a very prolific species. Swee and McCrimmon observed egg numbers ranging from 36,000 eggs in a 15.5-inch (394-mm) fish to 2,208,000 eggs in a 33.5-inch (851-mm) fish. The latter weighed 22.3 pounds (10.1 kg). The adhesive eggs, each about 1 mm in diameter, are deposited randomly and become attached to submerged weeds, grasses, or roots. Swee and McCrimmon observed spawning in Lake St. Lawrence and provided a series of observed water temperatures and hours to hatching of fertilized eggs. They concluded that eggs laid on the marsh vegetation would normally hatch within 3–6 days after fertilization depending on water temperature. Fish (1932) described larval stages from 10 mm to 30.75 mm and provided figures of 10 and 13.3 mm stages. McCrimmon (1968) provided additional information on larval development, including scale formation (McCrimmon and Swee 1967). Scale formation becomes evident at lengths of 16–18 mm and is apparently completed at lengths of 22–25 mm. *See also* Mansueti and Hardy (1967) for additional illustrations and description of larval stages in the Chesapeake Bay region.

Growth rates depend on many factors, such as availability of food and temperature, but carp usually attain lengths of 5.1–7.5 inches (130–190 mm) in southern Ontario waters during the first growing season. Scales are most often used for age determination but fin spines (English 1952) and opercular bones (McConnell 1952) have also been shown to be useful in age determination. McCrimmon noted that males became mature at ages 3 and 4, females at ages 4 and 5.

The spawning population in Lake St. Lawrence was composed of carp ranging from age 2 to age 16.

McCrimmon (1968) observed that the normal life span of carp in North America seldom seems to exceed 20 years, although in Europe and Asia they have been credited with much greater life expectancy and Regan (1911) considered that they live to ripe old age but noted that claims to ages of 150 years had not been substantiated.

Carp caught commercially frequently exceed 10 and even 15 pounds in weight, depending on the area. Trautman (1957) recorded a weight of 58 pounds for one caught in the Ohio waters of Lake Erie. McCrimmon (1968) reported that he had been advised that, in recent years, commercially caught carp ranging from 35 to 50 pounds were caught in Georgian Bay, Lake Ontario, Lake Simcoe, and the Trent Canal system. The largest carp observed by the present authors was a 39-pound fish caught in a poundnet near Port Dover on Lake Erie.

Carp are omnivorous and consume a variety of plant and animal tissues. The grinding of plant tissues is greatly facilitated by the molarlike surfaces of the pharyngeal teeth. A carp will suck up a mouthful of bottom ooze and detritus, expel it into the water, and select the food items. Many kinds of aquatic insects, crustaceans, annelids, and molluscs are prominent among the animals eaten; plant tissues include many kinds of weed and tree seeds, wild rice, aquatic plants, and algae. Carp will even feed directly at the surface on floating animal organisms or algae.

Young carp must fall prey to a variety of predaceous fishes and birds, although there is little direct evidence. Certainly, once carp attain a weight of 3 or 4 pounds they probably have few enemies other than man for they are exceedingly wary, and the heavy covering of thick scales provides a most effective external armament against such predators as the sea lamprey.

The parasites of carp in Canadian waters or United States Great Lakes waters have been studied and reported upon by Bangham and co-workers. These reports covered populations in Lake Erie (Bangham and Hunter 1939), South Bay, Lake Huron in Ontario (Bangham 1955), and the Fraser and Columbia rivers in British Columbia (Bangham and Adams 1954). The carp carried a small parasite fauna of trematodes, cestodes, nematodes, and acanthocephalans but, as noted by Bangham and Adams, carp were usually free of parasites and those they did carry were often gill flukes or external forms.

Hoffman (1967) provided a long list of parasites, in many groups, but with particular reference to species found in European carp populations.

Relation to man The first comprehensive review of the effects of carp populations on the Canadian aquatic environment and the associated faunas was provided by McCrimmon (1968). From this and other publications, such as Sigler (1958) on the ecology and use of the carp in Utah, it is apparent that there is a great need for imaginative and intelligent approaches to the utilization and management of carp populations. Carp are tolerant of, and indeed thrive in, waters rendered unsuitable by accelerating eutrophication for the more traditionally desirable species, such as yellow perch and smallmouth bass. Hence, they are probably increasing in numbers.

Carp are considered detrimental to native fish populations because they increase the turbidity of the water and uproot and destroy submerged aquatic vegetation that is essential for the survival of native species, since such growth provides cover, food, and sometimes spawning sites. They also adversely affect duck populations by the destruction of rooted aquatic plants in marshes, and control measures, such as fencing, have been applied in western Canada.

On the positive side, young carp are probably consumed by such game fishes as northern pike, muskellunge, and largemouth bass, although to what extent is not known. Little angling pressure is applied to carp in Canadian waters so far as we are aware, although in some parts of the United States, notably Iowa, carp angling may be an important recreational resource.

The summer habit of rising to the surface and even feeding on the floating algae, recently gave rise to some fanciful newspaper accounts in the Lake Ontario region. The large dorsal fins of surface-cruising carp, projecting from the surface of inshore waters of Lake Ontario, were seen by noted author–naturalist Farley Mowat, who, according to newspaper accounts, declared them to be shark fins!

As McCrimmon noted, the control of carp by various provincial and state agencies employing commercial fishing gear has not provided long term benefit except in confined local situations. Usual control measures involve the use of traditional commercial fishing gear, but other methods, such as electric shockers and stomach poisons, have also been tried and the methods and results were described by Loeb (1955, 1960a). The use of poison bait offers promise as a method of inexpensive control in controlled access areas. Coarse-fish removal programs are usually directed at carp, and occasionally carp may be harvested commercially by private enterprise. In Ontario, 800,000–1,000,000 pounds are landed annually, with a market value of about $70,000–$100,000. The wholesale price ranges from a few cents per pound to 18 or even 20¢ depending on market conditions, whereas the price of smoked, boneless carp exceeds $1.00/pound. Estimates of the quantity of carp marketed in North America in recent years ranges as high as 19 million pounds annually (McClane 1965).

As a food fish, small and medium-sized carp are marketed alive, cleaned and iced, or smoked. The smoked product is usually skinless, reddish or orange in colour, cut in strips, and is sometimes highly spiced.

Nomenclature

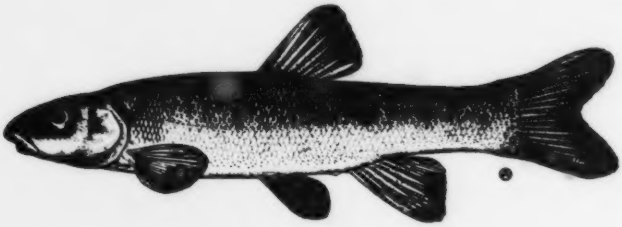
Cyprinus Carpio — Linnaeus 1758: 320 (type locality Europe)
Cyprinus carpio — Scott and Crossman 1969: 15

Etymology *Cyprinus* — ancient name of the carp, probably derived from *Cyprus*, abode of Venus, in allusion to its fecundity; *carpio* — Latinized form of carp.

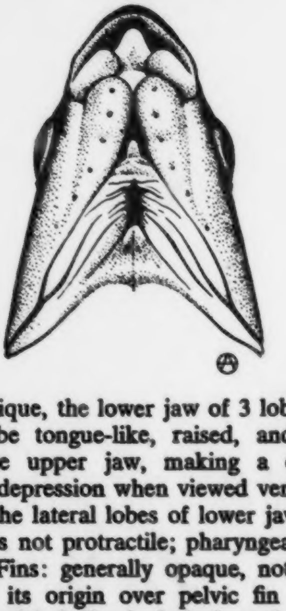
Common names Carp, German carp, European carp, mirror carp, leather carp. French common name: *carpe*.

CUTLIPS MINNOW

Exoglossum maxillingua (Lesueur)



Description Body stout, thick, its depth 15.9–21.4% of total length, average total length 3.5–4.5 inches (89–114 mm); caudal peduncle especially heavy. Head short, its length 18.7–21.9% of body length; eye diameter 27.2–37.5% of total length; snout bluntly rounded, its length 31.2–38.4% of head length; interorbital broad, its width 38.4–44.4% of head length; mouth unique, the lower jaw of 3 lobes, the centre lobe tongue-like, raised, and lying within the upper jaw, making a distinct gape (or depression when viewed ventrally) between the lateral lobes of lower jaw; premaxillaries not protractile; pharyngeal teeth 1,4–4,1. Fins: generally opaque, not clear; dorsal 1, its origin over pelvic fin origin, rays 8; caudal shallowly forked; anal 1, rays 7; pelvics small, origin below dorsal origin, rays normally 8, sometimes 9; pectorals short, broad, rays 13–16. Scales cycloid, small, persistent, 50–53 in lateral line; lateral line complete. Peritoneum silvery white. Vertebrae 38(2).



Colour Overall colouration rather dusky, olive-green on the back becoming leaden silvery on sides and light below. Fins generally dusky, a distinct round spot at the base of caudal rays that becomes indistinct on specimens over 3 inches (76 mm) long.

Distribution The cutlips minnow is confined to northeastern North America, ranging from the upper St. Lawrence River and eastern Lake Ontario drainage south in the northeastern United States, east of the Appalachian Mountains to the Roanoke River drainage of Virginia.

In Canada, the cutlips is confined to warm, clear, gravelly streams of the St. Lawrence River and its tributaries from at least the Saint-François River drainage of Lac St. Pierre, in Quebec, upriver in the St Lawrence River system, including the Lake Champlain drainage, to the vicinity of Ivy Lea on the north shore of Lake Ontario basin in eastern Ontario.

Biology The cutlips minnow spawns in spring, but no observations have been reported from the Canadian range. However, Evelyn Van Duzer (1939) published detailed observations on its spawning activities in the Susquehanna drainage of New York State which are the source for most of the following.

Spawning takes place in May, June, and July over a gravel nest. In the year of observation no nests were built before May 15, and nest building was carried on in earnest during June but terminated by July 11. The nests, which are more or less circular, flat-topped mounds of stones, may measure 12–18 inches (305–457 mm) in diameter and are 3–6 inches (76–152 mm) deep. They are composed of stones measuring ½–¾ inch (13–19 mm) and built by a single male, each stone being selected and carried in the mouth. The search for suitable stones sometimes leads to stealing from other nests. The larger the male, the larger the stone he may carry. The nest is always built in a section of stream with sufficient current to maintain constant change of water, never in an area having a growth of rooted aquatic plants, but preferably near or under a protecting log or large rock. Flat stones on a stream bed are apparently highly desirable for nesting.

Mating occurs when the nest is completed to the satisfaction of the male, who will drive off females as readily as other fishes until the nest is built. The female approaches the nest, the two align themselves side by side, the female slightly behind on the upstream slope of the nest, the bodies are curved in a characteristic manner very close to the gravel, and the release of eggs and sperm takes place in 2–4 seconds. A single male may mate with the same female more than once and with many females during the spawning period, which lasts up to 6 days early in the season but for as few as 3 days in late-season spawning.

The males rework the nest vigorously during spawning, but after spawning their activities on the nest cease in 2–4 days. The females take little part in the care of the nest except occasionally between mating acts, when they may rework the gravel a little.

The eggs become lodged only in the gravel on the upstream part of the nest to a depth up to 3 inches. They measure about 2 mm in diameter when deposited, or shortly after, and are yellowish in colour. The time to hatching is apparently not known, but the young remain in the nest for about 6 days after hatching, until they reach lengths of 9–10 mm.

The males attain a larger size than the females. Van Duzer stated that the majority of spawning males observed by her were 4.5–5.5 inches (114–140 mm) long. The largest specimen in the ROM collection measures 4.6 inches (117 mm) total length.

Most observers agree that the cutlips is a slow-moving, bottom-living minnow, preferring clear, warm, gravelly bottom streams relatively free of rooted plants and silt, but dwelling mostly under stones in quiet pools. Food consists mainly of aquatic insect larvae and molluscs, although detailed food studies have not been conducted.

Possibly the greatest enemy of the cutlips minnow is the degradation of the aquatic environment since, in order to survive, they require clear, silt-free streams without excessive plant growth. The common shiner *Notropis cornutus* may also be considered an enemy, since prespawning males and even spawning pairs will harass the sluggish but aggressive cutlips males during the latters' spawning activities, for the common shiner habitually uses the nests of other minnows for spawning sites. Prolonged harassment can apparently cause cessation of spawning by the cutlips. Thus a deterioration in the quality of the habitat of the cutlips in the presence of a stable population of common shiners could be disastrous for this sluggish and peculiar minnow. In 1943, Toner reported that bait dealers considered it to be not uncommon in the St. Lawrence around Ivy Lea and in the Delisle River below Alexandria, but that was 30 years ago and may not apply today.

Hoffman (1967) listed only trematodes, five species in all, from this minnow in North American waters. Wagner (1969), studying a collection of fishes from Spring Creek, Centre County, Pa., recorded two leeches, *Illinobdella alba* and *I. moorei* on the cutlips minnow.

Relation to man The cutlips is occasionally used as a bait minnow but many years ago Dymond (1937) noted that local fishermen in the Ivy Lea region of Ontario called it "eye picker" because of the belief that it would pick out the eyes of other fishes held in the same bait pail. Presumably, this belief is related to the peculiarly shaped lower jaw, but we can offer no opinion on the validity of the claim.

Nomenclature

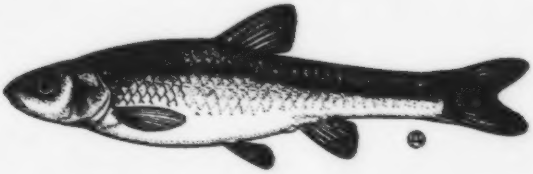
Cyprinus maxillingua	— LeSueur 1817c: 85 (type locality Pipe Creek, Md.)
Exoglossum Lesurianum	— Rafinesque 1818e: 420
Exoglossum maxillingua	— Scott 1967: 70

Etymology *Exoglossum* — outside; tongue; *maxillingua* — *maxilla* — jaw; *lingua* — tongue.

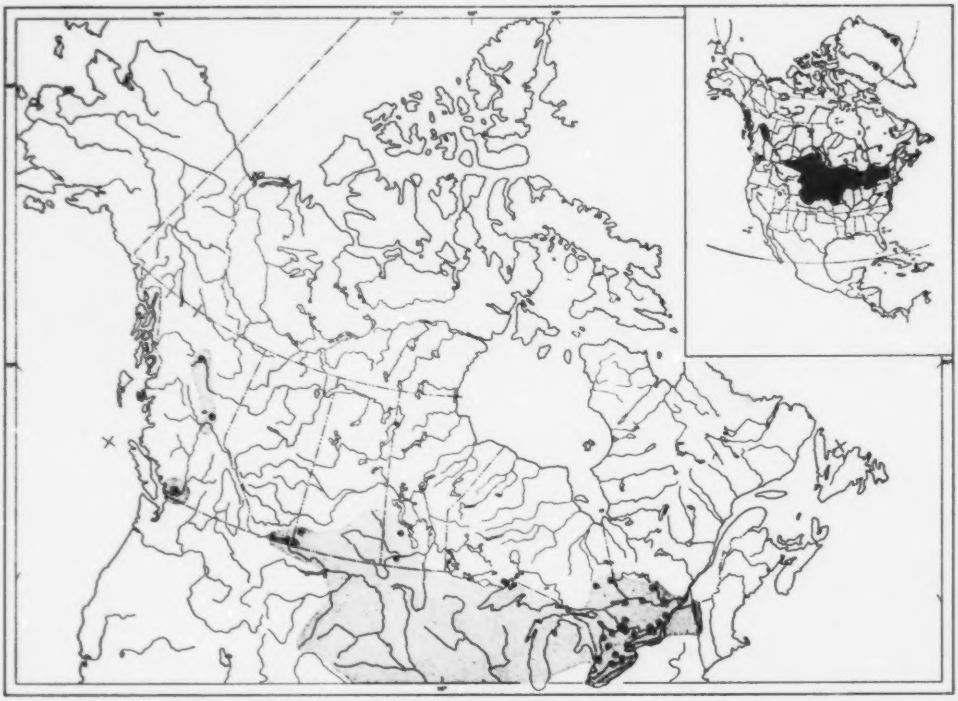
Common names Cutlips minnow, cutlips, eye-picker, little sucker. French common name: *bec-de-lièvre*.

BRASSY MINNOW

Hybognathus hankinsoni Hubbs



Description Body slender, not strongly compressed laterally, elongate, average length 2.5 inches (64 mm), body deepest before dorsal fin, depth 16.1–25.0% of total length. Head wide, bluntly triangular, its length 19.2–24.3% of total length; eye moderate, its diameter 21.4–33.3% of head length; snout rounded, slightly overhanging upper jaw, long, its length 27.2–36.3% of head length; interorbital wide, its width 35.7–44.4% of head length; mouth small, subterminal, slightly overhung by snout, gape extending to about below nostril; pharyngeal teeth 0,4–4,0, not hooked, with oblique grinding surfaces. Fins: dorsal 1, its origin slightly in advance of pelvic fin origin, rounded, rays 8(65), rarely 7(1); caudal forked; anal 1, its origin slightly behind or equal to margin of depressed dorsal, rays usually 8(36), sometimes 7(18), rarely 6(1), or 9(1); pelvics originate behind dorsal fin origin, rays 8(56); pectorals rather small, rays usually 13(23), occasionally 14(9), but rarely 15(2). Scales cycloid, with about 20 radii of varying lengths; lateral line complete, lateral line scales 36–41. Peritoneum uniformly black;



intestine elongate, distinctly coiled on right side. Vertebrae 35(4), 36(7), 37(1) in Ontario and Quebec; 35(2), 36(2), 37(6) in Saskatchewan.

Nuptial tubercles fine, on middle rays of pectoral fins of males only.

Colour Back olive-green to brown with distinct brassy reflections on the sides and creamy white below. No special breeding colours are known.

Distribution The brassy minnow occurs from the upper St. Lawrence River and Lake Champlain region of New York, west through southern Ontario and Michigan, west through the Arkansas and Missouri rivers to Colorado, Wyoming and Montana, north to Alberta; in British Columbia in the Fraser River and the headwaters of the Peace River. The known distribution was discussed and plotted by Bailey (1954) before range increases in the northwest were known.

In Canada, this species occurs in the upper St. Lawrence River of Quebec and Ontario, through southern Ontario north at least to Timiskaming District and Thunder Bay but there are no records for northern Lake Huron or eastern Lake Superior drainages; southern Manitoba, Saskatchewan (Scott 1957a), and Alberta, in Milk River and tributaries (McAllister 1962a; Willock 1968; Henderson and Peter 1969), and from several localities in British Columbia, including the lower Fraser valley, the upper Fraser near Prince George, and Parsnip River, of the Peace River system. It was first discovered in British Columbia in 1952 in the lower Fraser valley and reported by Carl and Clemens (1953).

Although originally thought to have been introduced to British Columbia waters, its widely scattered distribution indicates that it is a native species.

Biology The breeding habits of the brassy minnow are apparently unknown; at least details of spawning have not been reported. Spawning probably occurs in May or June and it is assumed that the pattern resembles that reported for *Hybognathus nuchalis*, and that eggs are deposited in quiet water over a silt bottom. Dobie et al. (1956) suggested that adhesive eggs (which seems unlikely) were deposited over sand, weed, or debris when water temperatures reach 50°–55° F (10.0°–12.8° C). McPhail and Lindsey (1970) noted that females taken in the Peace River drainage June 16 had not spawned and some taken June 28 in the same region had not completed spawning.

Dobie et al. suggested that maturity is reached in 2 years at a length of 2.5—3.0 inches (64–76 mm). The largest specimen seen by us measured 3.8 inches (97 mm).

As noted by Dymond (1939), and as its distribution would suggest, the brassy minnow lives in cooler water than the silvery minnow. In eastern Canada, especially in Ontario, it does occur in creeks and brooks, but it is often more abundant in the cool, dark acid waters of silt-bottomed bog ponds, where it usually occurs in association with *Chrosomus eos*, *Chrosomus neogaeus*, *Pimephales promelas*, and *Semotilus margarita*. Toner (1943) noted that wherever it occurred in numbers, predatory fish were absent. In the northwestern part of its range, McPhail and Lindsey noted that brassy minnows occur in slow streams, boggy lakes, and shallow bays.

Its food is believed to consist mainly of phytoplankton and other algae, zooplankton and some aquatic insects. The long, looped intestine and black peritoneum suggest that it is adapted to feeding on plant material.

We have no information about predators of the brassy minnow but assume that natural enemies would include brook trout, and such fish-eating birds as mergansers and kingfishers.

There are no reports of parasitism of the brassy minnow in Canadian literature. Hoffman (1967) listed only trematodes, *Octobothrium* sp., and the larval forms of *Neascus* sp., *Posthodiplostomum minimum*, and *Uvulifer ambloplitis*.

Relation to man The brassy minnow is considered to be a valuable bait and forage minnow in many parts of the United States. The statement by Dobie et al. (1956) that it was one of the most common and widespread bait fishes of the Great Lakes region seems extravagant since this does not apply to Canadian waters where, in our experience, its use as a bait species is uncommon. However, in defence of this opinion is the statement by Underhill (1957) that it was probably the most abundant minnow in Minnesota. With the possible exception of small, isolated ponds, it has never been so abundant in Canada.

Nomenclature

Hybognathus hankinsoni — Hubbs and Greene 1928: 382, 389 (lectotype, UMMZ 84266, L. Superior watershed, Marquette Co. Mich.)

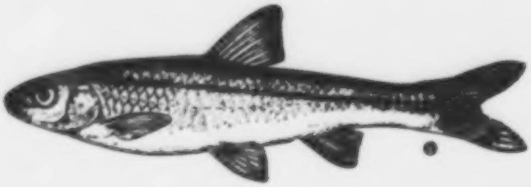
A specimen caught at Clarkson, Ont., (ROM 3662) was designated a paratype by Hubbs in correspondence, November 9, 1927. *See also* Dymond et al. (1929)

Etymology *Hybognathus* — protruding jaw; *hankinsoni* — after T. L. Hankinson of Michigan.

Common names Brassy minnow. French common name: *méné laiton.*

SILVERY MINNOW

Hybognathus nuchalis Agassiz



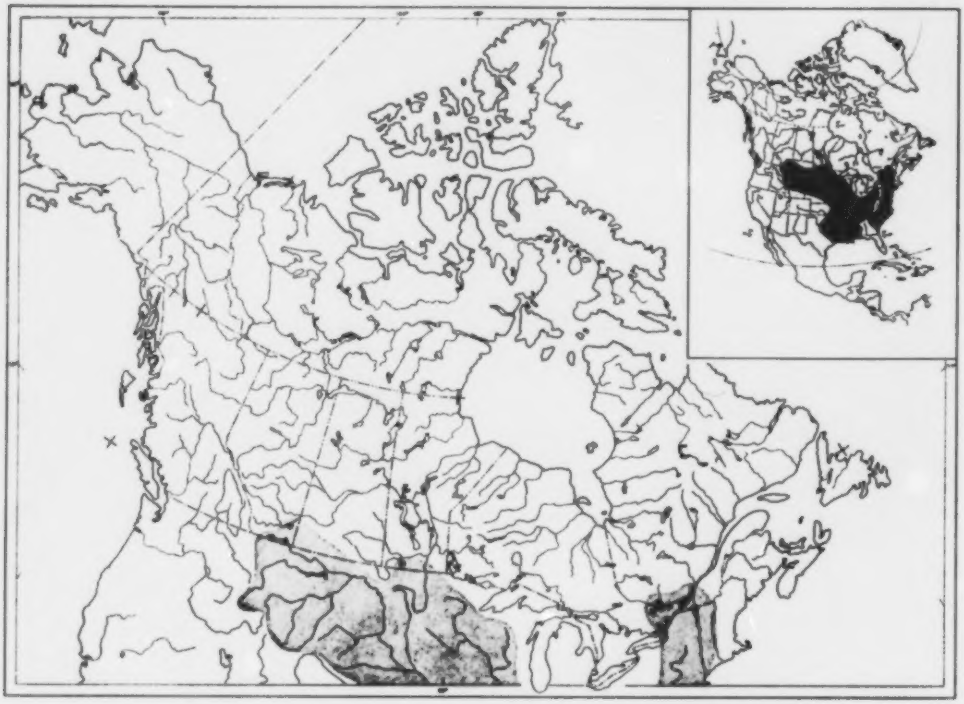
Description Body moderately laterally compressed, elongate, average length about 3 inches (76 mm), body deepest in front of dorsal fin, its greatest depth 17.3–20.8% of total length; caudal peduncle rather stout. Head bluntly triangular, short, its length 18.3–21.0% of total length; eye moderately large, its length 25.0—33.3% of head length; snout rounded, overhanging mouth, its length 30.7–35.7% of head length; interorbital wide, its distance 35.7–44.4% of head length; mouth subterminal, slightly overhung by snout, the gape extending to below nostril, not to anterior margin of eye; pharyngeal teeth 0,4–4,0; not hooked but with distinct grinding surface. Fins: dorsal 1, its origin slightly in advance of pelvic fin origin, posterior margin somewhat falcate, rays 8(42); caudal distinctly forked; anal 1, its origin behind posterior margin of depressed dorsal, rays usually 8(38), occasionally 9(4); pelvics originate slightly posterior to dorsal fin origin, rays usually 8(19), seldom 7(1); pectorals relatively short, rays 15(10), or 16(10). Scales cycloid, with 8–11 long radii; lateral line complete, lateral line scales 38–40. Peritoneum uniformly black; intestine elongate, distinctly coiled on right side. Vertebrae usually 37(11), sometimes 36(3), or 38(8).

Nuptial tubercles small but numerous on males, sparse on females, on top and sides of head, on scales of back and sides especially anteriorly, and on fins, particularly on upper sides of paired fins.

This description is based on examination of Quebec and Ontario specimens.

Colour Both males and females are strikingly silvery creatures, whence the common name, but during the spawning season the males exhibit light yellow along the sides and on the lower fins. Raney (1939) noted that the males were much darker than females and that the differences in colouration of Cayuga Lake, N.Y., specimens were sufficiently great to cause local bait fishermen to regard them as different species.

Systematic notes Two subspecies have been described, *Hybognathus nuchalis nuchalis* Agassiz, the western silvery minnow, and *H. n. regius* Girard, the eastern silvery minnow. Both subspecies are represented in Canada (*see Distribution*) since the Alberta populations have been ascribed to the western subspecies, although not all ichthyologists are agreed on this point. Indeed Alberta populalations warrant further study, particularly in view of recent work on the genus. Pflieger (1971) noted that *nuchalis* and *regius* could be considered as distinct species (p. 365). He also recognized *H. argyritis* Girard for the form of *Hybognathus* from the Missouri River system, not identifiable as *H. placitus*. Significantly, Pflieger noted that the seven type specimens of *H. argyritis* were taken from the Milk River in Montana. The first published specimens of *H. nuchalis* from Alberta were caught in the Milk River



(Willock 1968). Willock's specimens, and all Alberta *nuchalis*, should be re-examined to confirm their identity.

For further information regarding western *Hybognathus* species *see* Bailey and Allum (1962), Al-Rawi and Cross (1964), and Pflieger (1971).

Distribution The silvery minnow is a central North American form and has a peculiar distribution, being found from southwestern Quebec and southeastern Ontario on the northeast, south to Georgia, Louisiana, and Mississippi; north and west in the Mississippi and Missouri River systems, excluding all of the Great Lakes except eastern Lake Ontario, to Montana and southern Alberta.

In Canada, it is restricted to the waters of the upper St. Lawrence River from at least the Nicolet River of eastern Lac St. Pierre, upriver through Lac St. Louis to the Ottawa River at least to about Ottawa, upstream in the St. Lawrence River to at least Gananoque. It is not known to occur elsewhere in Canada except in southern Manitoba and southern Alberta. It gained entry to Alberta probably via the Milk River, a tributary of the upper Missouri River. The first Alberta specimen known to us was one, 3.65 inches (93 mm) in standard length, caught in the South Saskatchewan River in 1963 (Henderson and Peter 1969), but the first Alberta records were published by Willock (1968), based on specimens taken in the Milk River. Willock also provided a discussion of the probable history of its occurrence in the area.

Biology The spawning habits of the silvery minnow were described in detail by Raney (1939) from a study of populations in the Cayuga Lake drainage of New York State. There, spawning occurred in late April and early May 1938 at temperatures of 55.4°–68.9° F (13.0°–20.5° C).

Although there are no observations published for Canadian waters, it is presumed that spawning would take place when water temperatures were about the same, possibly in May. Prior to spawning, the adults migrate from the inshore waters of the lakes or larger rivers to well-vegetated lagoons or slow-moving lower reaches of tributary streams. Raney noted that the silvery minnow was unique among northeastern minnows in that it laid its nonadhesive eggs on the bottom ooze in quiet backwaters. Water depth was about 1 foot, and the shallow shore waters heavily vegetated with emergent grasses and reeds provided effective cover.

Spawning commenced about 10 AM, continued until 4 PM, but did not continue after dark. The ripening female remains in deeper water, moving into inshore shallows when ripe, where she is joined by 1 to 10 males who align themselves one on either side, the remainder ranging around, above and below, all swimming swiftly. Those on either side of the female press tightly against her. Raney noted that the eggs and sperm were usually released when the three vibrated for a second or two, most often in water 2–6 inches deep, near newly sprouted grasses. Some evidence suggested that the spawning period may be extended or prolonged.

The eggs measured 1 mm in diameter and their number varied from 6600 in a 90-mm female (standard length) to 3000 in 68- to 70-mm ones and 2000 in a 60-mm female. Raney found that the eggs were well developed in females caught in late fall.

Newly hatched larvae measured 6 mm total length. Both newly hatched and 14-mm fry were illustrated by Raney. About 2 weeks after hatching, the young appear in small schools near shore among emergent vegetation. Raney found them to be 1.5 inches (38 mm) total length by July 15 and about 2 inches (51 mm) by August 5. Some females are thought to spawn when 50–55 mm long (standard length) and only 1 year old, but males probably do not spawn until their second year. Mansueti and Hardy (1967) illustrated and described larval stages in the Chesapeake Bay region.

The largest spawners examined by Raney (1939) were a male 3.3 inches (83 mm) and a female 3.9 inches (100 mm) standard length, whereas the largest specimen seen by the present authors was 4.7 inches (120 mm) total length.

The usual habitat is the quiet, weedy inshore waters of lakes and large rivers. It apparently prefers wide waters.

Detailed food studies have not been conducted but bottom ooze and algae have been reported from the stomachs and apparently constitute the main food. In the propagation experiments reported by Raney (1942) the fish were not fed.

The young of the silvery minnow possibly constitute important forage for the young of game species inhabiting the same weedy, inshore waters although direct evidence is lacking. Raney (1942) noted that they were regarded as important bait for pickerel (*Esox niger*), and northern pike.

Hoffman (1967) listed three species of trematodes, one protozoan, and the larval form of the cestode *Ligula intestinalis* as parasites of the silvery minnow in North American waters.

Relation to man The silvery minnow is considered to be a good bait minnow and is widely used in parts of the United States such as central New York State, but less so in others such as Iowa where it is said to die quickly in minnow pails. Raney (1942) described a method of pond propagation and noted that it offered promise as a food fish in the artificial culture of muskellunge.

It was seined by bait dealers in the Ottawa River (Toner 1943), and possibly also in the St. Lawrence River in the Gananoque–Brockville region. In the latter region it is abundant at times and is probably an important forage fish.

Although not eaten in Canada, Schwartz (1963) remarked that in Maryland it was esteemed by many when deep-fried in oil.

Nomenclature

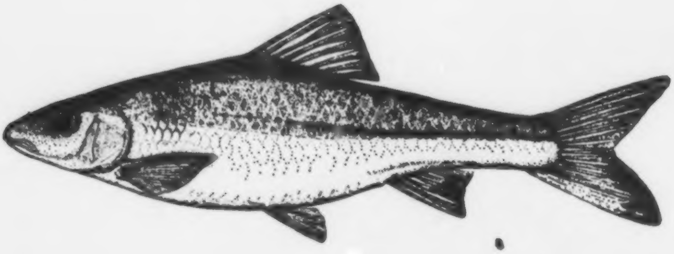
Hybognathus nuchalis — Agassiz 1855: 224 (type locality Quincy, Ill.)
Hybognathus regius Girard — Girard 1857a: 209
Hybognathus nuchale Agassiz — Evermann and Goldsborough 1907a: 94
Tirodon amnigenus Hay — Hubbs 1947: 176

Etymology *Hybognathus* — protruding; jaw; *nuchalis* — pertaining to the nape.

Common names Silvery minnow. French common name: *méné d'argent.*

SILVER CHUB

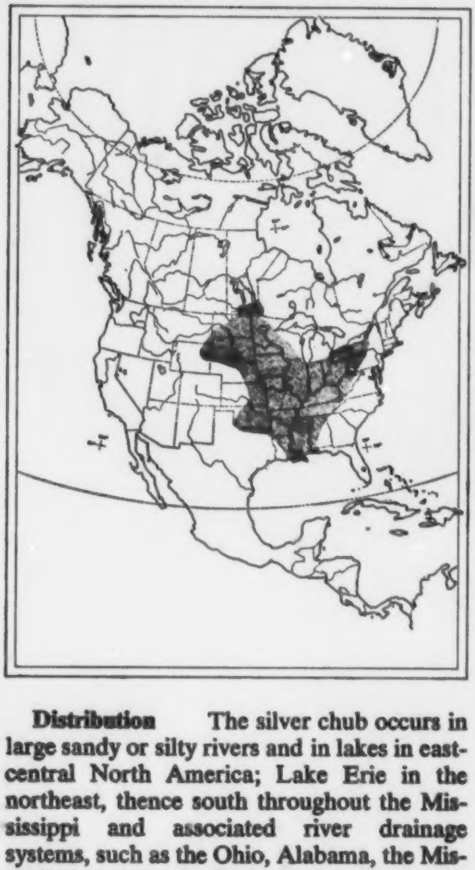
Hybopsis storeriana (Kirtland)



Description Body stout and rather thick, total average length about 4–6 inches (102–152 mm), body depth 17.0–24.1% of total length. Head length relatively short, 16.3–20.8% of total length; eye rather large, its diameter 23.5–33.3% of head length; snout relatively long, 31.5–40.0% of head length; interorbital broad, its width 30.0–37.2% of head length; mouth moderate, the gape terminating before anterior margin of eye, a well-developed barbel at posterior end of maxillary nearly always present; pharyngeal teeth 1,4–4,1. Fins: dorsal 1, its origin distinctly in advance of pelvic fin origin, rays 8 (23 specimens); caudal well developed, distinctly forked (*see* section on *Colour*); anal 1, moderate in size, its origin behind tip of depressed dorsal, rays usually 8(21), rarely 7(2); pelvic rays usually 8(17), rarely 9(1), a distinct pelvic axillary scale present; pectorals relatively small, pointed, rays usually 17(14), occasionally 16(2), or 18(2). Scales cycloid, large, conspicuous and deciduous, 38–41 in lateral line; lateral line complete, only slightly decurved. Peritoneum silvery. Vertebrae 38(3), 39(10), 40(3), or 41(1).

Nuptial tubercles apparently present on males but no specimens or data available for description.

Colour Dorsally pale grey-green, becoming silvery on sides and silvery white below. Dark pigment or melanophores are not conspicuous but a faint dusky lateral band is usually present. Caudal fin lightly pigmented overall but with the lower three or four rays completely unpigmented and immaculate white (this character usually remains apparent even on preserved specimens).



Distribution The silver chub occurs in large sandy or silty rivers and in lakes in east-central North America; Lake Erie in the northeast, thence south throughout the Mississippi and associated river drainage systems, such as the Ohio, Alabama, the Mississippi proper, the Red (in Arkansas), the Kansas, Missouri (and tributaries), and Red River (of North Dakota and Manitoba).

In Canada this species occurs in Ontario in Lake Erie where it was common in earlier years. However, attempts to obtain specimens, with the cooperation of the Ontario Department of Lands and Forests and of commercial fishermen, over the latter part of the 1960's were in vain. The last positive record known to us was a report of capture off Cleveland during exploratory fishing by the United States Fish and Wildlife Service vessel *Cisco*, in 1957 (Cruise II, May 21–June 3, 1957). The present status of the species in Lake Erie is in doubt but obviously it is rare.

In Manitoba, it is recorded from the Red River system and the Assiniboine River at Winnipeg. Keleher and Kooyman (1957) stated the known northern limit of range had been extended to include St. Andrews Locks near Selkirk.

Biology Published information on the biology of this species is extremely limited. One of the most extensive studies of interest to Canadians is E. C. Kinney's unpublished Ph.D. thesis (1954) at Ohio State University.

For Lake Erie populations, the exact time and place of spawning is not known but statements by McCormick (1892) quoted by Trautman (1957), Fish (1932), and Kinney suggest that spawning occurred in June, possibly in late May, in Ohio waters. Kinney considered that most spawning took place at temperatures above 69.8° F (21° C). Spawning is thought to occur in open water, but there is no direct evidence. Trautman reported that spawned adults were frequently found on the beach in June and July and it seems probable that spawning mortalities were not unusual although we know of no evidence of such mortalities on the Canadian side of Lake Erie.

The number of eggs was given by Kinney as 365 + 746 times the ovary weight, in grams. Time to hatching is not known but Fish (1932) described and figured four larval stages from 5 to 21 mm and noted that larval stages to 7.5 mm were taken in Lake Erie from Buffalo to Rondeau in bottom hauls, at 18–20 metres in the latter part of June and early July.

Age can be determined from scales according to Kinney, who gave the time of annulus formation as May to mid-June. For the period of July to December, the following standard length ranges, in mm, were found: age 1, 55–145; age 2, 110–155; age 3, 145–170. A few individuals apparently reach age 4 but die after spawning. Trautman gave the length of the largest specimen as 9.1 inches (231 mm), weight 6 ounces (170 g). Total length of longest specimen on hand from Canadian waters of Lake Erie is 7.9 inches (201 mm).

Trautman (1957) reported that the silver chub occurred in greatest abundance in Lake Erie waters at depths of 3–60 feet. It is said also to inhabit pools in slow-moving streams having clean sand or gravel bottom. Extensive day and night seining on the Canadian shores of Lake Erie in the late 1940's and early 1950's, failed to yield a single specimen in waters of even 6 feet in depth and rarely were specimens taken in the fall commercial seining operations in inshore waters of Long Point Bay. Specimens caught in Canadian waters were usually taken in small mesh gillnets.

Young silver chub consumed cladocerans, copepods, and chironomids, but the major food supplies of adults were mayflies of the genus *Hexagenia*, until these disappeared from the Lake Erie fauna, when greater use was made of chironomids and *Gammarus*.

Bangham and Hunter (1939) examined 31 specimens of silver chub from Lake Erie, 20 of which were parasitized by some or all of trematodes (3), cestodes (1), nematodes (1), and acanthocephalans (1). Hoffman (1967) listed one parasite only, the trematode *Dactylogyrus texomonensis*.

Relation to man Since the silver chub had, at best, only marginal distribution in Ontario, its contribution to the economy of our waters was small. Its apparent disappearance from Lake Erie is regrettable, since it suggests an ever-narrowing faunal base in that woefully abused body of water.

Nomenclature

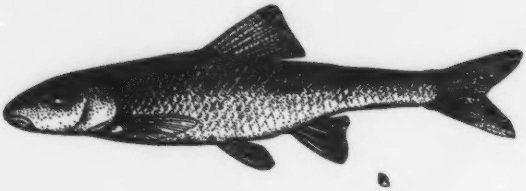
Rutilus Storerianus — Kirtland 1844a: 71 (type locality Lake Erie)
Leuciscus Storerianus — Kirtland 1844b: 199–200 (description)
Hybopsis storerianus (Kirtland) — Jordan and Evermann 1896–1900: 321
Erinemus storerianus Kirtland — Hubbs 1926: 30
Hybopsis storeriana — Speirs 1951: 18

Etymology *Hybopsis* — gibbous; face; *storeriana* — after D. H. Storer.

Common names Silver chub, Storer's chub. French common name: *méné à grandes écailles*.

GRAVEL CHUB

Hybopsis x-punctata Hubbs and Crowe



Description Body slender, small, average total length about 3 inches (76 mm), only slightly compressed, body depth 14.6–16.7% of total length. Head elongate, its length 20.0–21.3% of total length; eye comparatively large, its diameter 30.0–33.3% of head length; snout rounded, overhanging mouth, comparatively long, 37.9–46.7% of head length; interorbital width moderate, 22.2–27.6% of head length; mouth small, inferior, overhung by snout, a slender, small but conspicuous barbel near the end of the maxillary; pharyngeal teeth 0,4–4,0. Fins: all fins more or less clear; dorsal 1, base short, its origin distinctly in advance of pelvic fin origin, rays 8; caudal distinctly forked; anal small, its origin behind insertion of dorsal fin, rays 7; pelvics comparatively small, rays 8; pectorals narrow, their tips reaching a point under dorsal fin origin, rays 13–16. Scales cycloid, large, about 43–45 in lateral line (Ontario specimens apparently have higher counts than those in USA); lateral line complete. Peritoneum uniformly dark brown. Vertebrae 37–39.

Nuptial tubercles very small, even minute, on head and branchiostegals and sometimes on most scales on anterior part of body.

Colour Overall colouration silvery, but olive-green dorsally, silvery on sides and silvery white below. Scale margins somewhat randomly outlined with black pigment along sides expressed in the form of X- or Y-shaped marks, usually only faintly evident on Ontario specimens (which do not show a prominent caudal spot, either).

Systematic notes As numerous authors have noted, this species was long confused with at least one other form. The Ontario population was reported by Radforth (1944), Dymond (1947), and Scott (1954) as *Erimystax dissimilis* (Kirtland). Hubbs and Crowe (1956) described the new species *H. x-punctata*, assigning the northeastern Ohio basin and Ontario populations to the subspecies *H. x-punctata trautmani*.

Distribution The gravel chub occurs only in east-central North America from Pennsylvania on the east, through the Ohio River basin in Ohio, Kentucky, Indiana, and Illinois; and in the Mississippi River system from Wisconsin and Minnesota south to Arkansas and Oklahoma; and an apparently isolated population in the Thames River, Ont.

Trautman (1957) noted that there were no acceptable Lake Erie drainage records but that the species has been reduced or extirpated from many parts of its former range in Ohio because of the silting over of gravel in streams. We know of no reports of the continued existence of the Thames River population since the capture of four specimens by D. Roseborough in August 1958.

Biology There seems to be little available biological information on the gravel chub. As the name suggests, it prefers gravel-bottomed streams and rivers, preferably slow-moving, deep ones, but if the gravel there becomes silted over, they will move into faster, shallow regions. *See* Trautman (1957) for a discussion of its habitat in Ohio.

Its food probably consists of aquatic insect larvae but detailed studies are not available.

Relation to man The gravel chub is much too rare to be of economic significance, but it and other rare forms are valuable in that their very presence tells much about the history of the continent and drainage connections in postglacial times. Their demise should serve as a warning that the environmental changes are sufficiently drastic to deny life to them.

Nomenclature

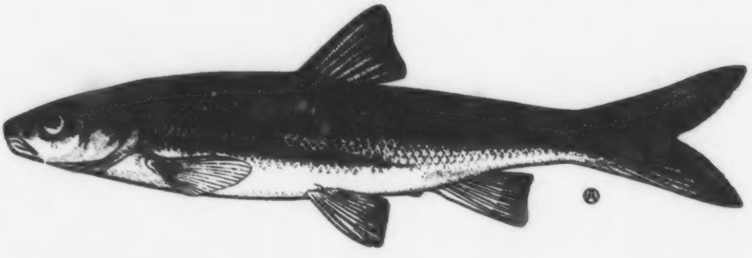
Hybopsis x-punctata	— Hubbs and Crowe 1956: 6 (type locality Gasconade River, Missouri)
Luxilus dissimilis	— Kirtland 1841b: 341
Erimystax dissimilis (Kirtland)	— Hubbs and Brown 1929: 24
	— Radforth 1944: 49
	— Dymond 1947: 20
	— Scott 1954: 57
	— Scott 1958: 16

Etymology *Hybopsis* — gibbous; face; *x-punctata* — *punctatus* — dotted.

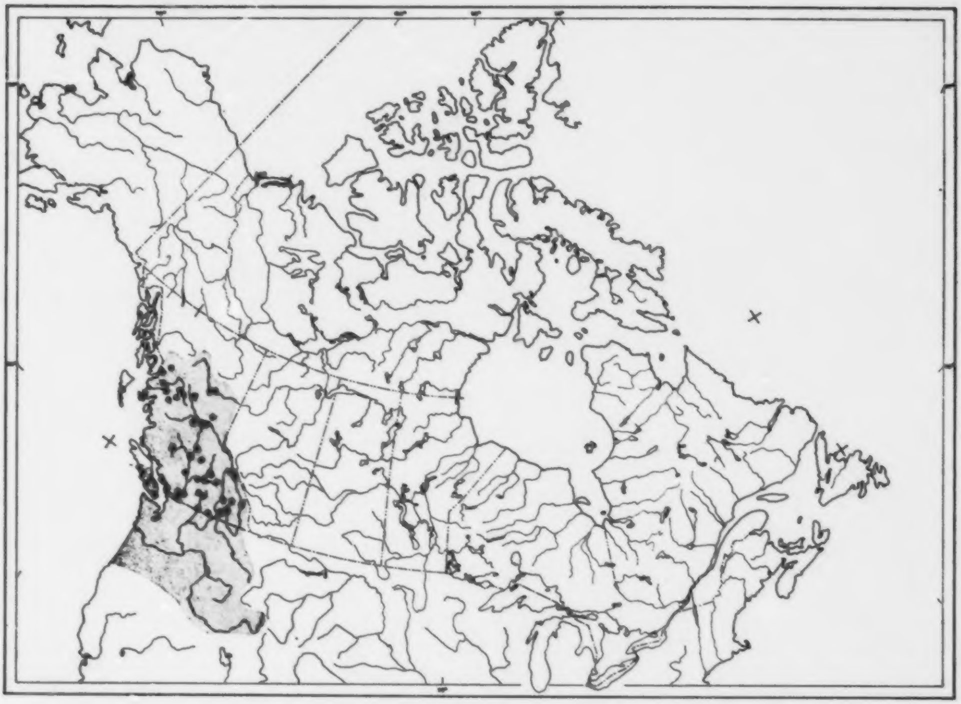
Common names Gravel chub, spotted chub. French common name: *gravelier*.

PEAMOUTH

Mylocheilus caurinus (Richardson)



Description Body elongate, averaging 4–6 inches (102–152 mm) long, not strongly compressed laterally, body depth greatest just before dorsal fin, the depth 15.2–17.7% of body length. Head relatively short, its length 17.4–19.3% of total length; eye moderate, its diameter 19.5–27.7% of head length; snout long, slightly overhanging mouth, its length 30.0–36.3% of head length; interorbital broad, its width 34–38% of head



length; mouth slightly inferior because of overhanging snout; a small barbel at each corner of the mouth; premaxillary protractile; pharyngeal teeth usually 1,5–5,1, with distinct grinding surfaces in adults, but hooked in young fish. Fins: dorsal 1, its origin slightly in advance of pelvic fin origin, rays always 8; caudal deeply forked; anal 1, originating clearly behind dorsal insertion, rays usually 8, occasionally 9; pelvics originating slightly posterior to dorsal fin origin, rays usually 9, occasionally 10; pectoral fin rays 15–18, usually 16 or 17. Scales cycloid, 68–79 in lateral line; lateral line complete. Peritoneum dusky. Vertebrae 44(1), 45(17), or 46(3).

Nuptial tubercles on breeding males, on head, including gill covers, and extending onto back.

Colour A brightly coloured minnow, with localized areas of red at the angles of the mouth, sometimes extending along the cheek and opercle to pectoral fin, and also along sides; breeding fish of both sexes are highly coloured, with red lower lips and the lateral red stripes well developed, but males have a green back, females a brown back. Mature fish are generally silvery with a dark back and two distinct lateral bands, one extending from behind the dorsal part of the operculum posteriorly to the caudal base, the lower or ventral one extending from end of operculum to above anal base.

Systematic notes For a review of the scientific nomenclature *see* Hubbs and Schultz (1931). The peamouth hybridizes with *Ptychocheilus oregonensis*, and the resultant hybrid, which is intermediate in most characters between the two parents, has been described in detail by Weisel (1954, 1955a, b).

Distribution The peamouth chub occurs in rivers and lakes in northwestern North America. It is found in British Columbia;

Vancouver Island and some smaller inland islands. Reported from Washington, Oregon, Idaho, and Montana.

In Canada it has been erroneously reported in Alberta from the Athabasca River at Athabasca. It is widespread in lakes and rivers in British Columbia; from the upper Peace River system, in waters near Hudson Hope, rivers on the Pacific slope from the Nass River in the north to the Columbia River system, and in the Fraser and Skeena River systems. On Vancouver Island peamouth chub are found in Holden and Fishhook lakes near Nanaimo, and in Kennedy and Cecilia lakes on the west coast. Known from Nelson Island off Jarvis Inlet, and from a lake on Bowen Island. Occasionally taken at sea at Spanish Banks (Carl et al. 1967).

Biology The spawning behaviour of the peamouth chub in shallow, shore waters of lakes was described at length by Schultz (1935) whose observations were made June 1, 1935, at Lake Washington, near Seattle, Wash. The spawners crowded into shallow water near shore, often in groups of 50–400 fish, the centre of each group separated from the centre of an adjacent group by 25–100 feet. The females were crowded by two or more males into an inch or two of water at shoreline where the eggs and sperm were emitted. The eggs are grey-green, adhesive, and settle to the bottom and become attached to stones and rubble. Schultz stated that the water temperature at time of spawning was 54° F (12.2° C). Carl et al. (1967) noted that in British Columbia, spawning took place in May or June. They noted further that ripe fish have been taken in streams near lakes but did not present evidence of stream spawning. They also observed that the newly hatched young remained in schools along shore, apparently moving into deeper water in late summer.

Rates of growth, fork length (in millimeters) at ages 1-5, have been reported by Clemens (1939) for Okanagan Lake, B.C., as follows: age 1 (51); age 2 (107); age 3 (142); age 4 (170); age 5 (198).

Clemens noted one fish, 9.75 inches (247 mm) long, in its 6th summer. Dymond (1936) reported the largest specimen encountered during his work in Cultus Lake had a fork length of 12.5 inches (318 mm).

In general, females grow faster than males and attain a larger size. Schultz said spawning females averaged 1.1 inches (28 mm) longer than breeding males; the females averaged 8.8 inches (224.6 mm) standard length and weighed 203.6 grams whereas males averaged 7.8 inches (197.8 mm) and weighed 123.8 grams.

This is a fish of the weedy shallows of lakes and rivers where it tends to form schools. It is unusual among cyprinids in that it has a limited tolerance to dilute sea water and is known to withstand brackish waters for a limited time. This special ability has probably enabled it to extend its range to Vancouver Island.

The peamouth is considered to be mainly insectivorous (Munro and Clemens 1937) and feeds on a wide variety of aquatic insects and their larvae such as chironomids, mayflies and caddisflies and some terrestrial insects (Clemens et al. 1939); it consumes a wide variety of planktonic crustaceans, molluscs, and occasionally small fishes (in some cases, sculpins).

The inshore spawning habits of the peamouth certainly expose it to easy predation by fish-eating birds and mammals. Munro and Clemens noted 13 occurrences of this species in American merganser stomachs.

Bangham and Adams (1954) examined 391 specimens of the peamouth chub from 23 locations in British Columbia, and found 370 parasitized. Parasites included trematodes, nemotodes, cestodes, acanthocephalans, and crustaceans. The degree of infection of individual fish was often quite high with acanthocephalans *Neoechinorhynchus rutili* and *Pomphorhynchus bulbocolli*, the cestode *Eubothrium salvelini*, and the trematode *Proteocephalus ptychocheilus*.

Hoffman (1967) listed trematodes, cestodes, nematodes, acanthocephalans, 1 crustacean, and glochidia (Mollusca) from this species in North American waters.

Relation to man We hear little about the angling and food qualities of the peamouth chub today but at one time, at least, it was utilized. Jordan and Evermann (1908) noted that in the Snake River and Flathead Lake regions it was called, erroneously, freshwater herring and whitefish and that in some areas of the Columbia basin it was served in hotels as whitefish. It was also said to have fair game qualities, to fight well when hooked, and to bite readily on a variety of baits such as salmon eggs and grasshoppers. Its large numbers further enhanced its importance.

Nomenclature

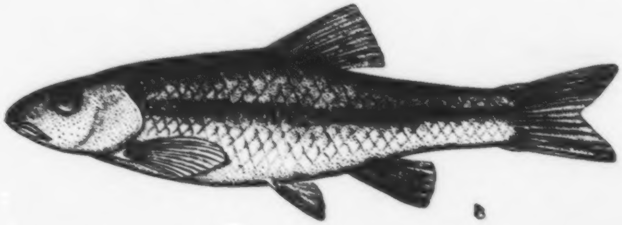
Cyprinus (*Leuciscus*) *caurinus* (Rich.) — Richardson 1836: 304 (type locality Columbia River at Fort Vancouver)
Mylocheilus lateralis Agass. & Pick. — Agassiz 1855: 231
Mylocheilus caurinus (Richardson) — Jordan and Evermann 1896–1900: 219
Clarkina caurina (Richardson) — Jordan, Evermann, and Clark 1930: 118

Etymology *Mylocheilus* — grinder; lip; *caurinus* — *caurus*, the northwest wind, hence *caurinus* — north western.

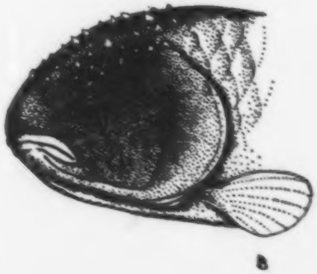
Common names Peamouth, peamouth chub, northwest dace. French common name: *méné deux-barres*.

HORNYHEAD CHUB

Nocomis biguttatus (Kirtland)



Description Body stout, heavy forward, elongate, average length about 3.5 inches (89 mm), deepest in front of pelvic fins, belly gently rounded, greatest body depth 19.6–24.6% of total length. Head bluntly triangular and wide, its length 21.8–24.1% of total length; eye diameter 21.0–37.5% of head length, small in large specimens; snout bluntly rounded, long, 29.1–42.1% of head length; interorbital width



24.1–50.0% of head length; mouth moderate, and terminal, or nearly so, snout not projecting beyond upper lip but lower lip included by upper lip; a distinct terminal barbel at the angle of upper and lower jaw, upper jaw not reaching to anterior margin of eye; pharyngeal teeth, 1,4–4,1 said to be usual but we have found at least one-third of specimens examined have only one row of teeth, i.e., 4–4, or 4–3. Fins: dorsal 1, opaque, its origin over or slightly behind pelvic fin origin, slightly pigmented, rays 8(44), rarely 7(1); caudal with shallow fork, tips rounded; anal 1, its origin behind dorsal insertion, rays 7(45), rarely 6(1); pelvics rather small, origin under or slightly in advance of dorsal fin origin, rays 8(30); pectorals well developed, rounded, rays usually 15(14) or 16(11), but sometimes 14(3) or 17(2). Scales cycloid, large, margin accentuated with melanophores, the angle subtended by the scale radii less than 90°, usually 70–75°; lateral line complete, almost straight, scales in lateral line 40–48. Peritoneum more or less uniformly brown but with darker speckles overlaid; intestine short. Vertebrae usually 38, sometimes 37 or 39.

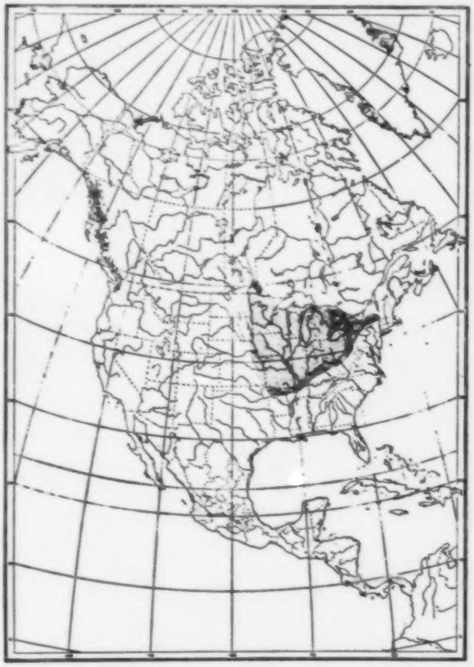
Nuptial tubercles well developed and obvious, usually more than 45, on head, extending from posterior snout through interorbital region to nape. Some pointing forward. Tubercles also developed on first few rays of pectoral fins.

Colour Overall colouration olive-brown on the back, silvery on sides, becoming creamy white below. Lateral band inconspicuous on living specimens but rather distinct on preserved ones. A caudal spot distinct on young fish but becoming vague on fish 3.5 inches (89 mm) long and over. Breeding males with a pronounced light red postocular spot and orange on dorsal and anal fins. Lachner (1952) noted an intense black lateral band present on breeding males but not present on specimens preserved several hours. Young fish with reddish caudal fin.

Systematic notes Members of this genus were placed in the genus *Hybopsis* in many recent publications, in particular the 1960 issue of the American Fisheries Society's *Checklist of Common and Scientific Names*, but the genus *Nocomis* was reinstated in the 1970 issue of the checklist.

Prior to 1925, hornyhead and river chubs were not recognized as distinct species and hence the early literature is confusing (Hubbs 1926; Trautman 1957).

See Lachner (1952) and, in particular, Lachner and Jenkins (1967) for a discussion of the systematics of fishes in the genus *Nocomis*. Hybridization has been noted with other species, such as *Notropis cornutus* (Trautman 1957), but hybrids between species of the genus *Nocomis* are rare.



Distribution The hornyhead chub occurs chiefly in clear, gravelly creeks from New York and Ohio west to Colorado and Wyoming, south to Tennessee, Arkansas, and Oklahoma. (*See* Lachner 1952, for detailed distribution in northeastern United States.)

In Canada, the species has a limited distribution and occurs only in Ontario and

Manitoba. In Ontario, it is restricted to streams of lakes Erie and St. Clair, and southern Lake Huron drainage, north to Huron County, but not in Lake Ontario drainage. Reported from southeastern Manitoba in the Birch River (49°49′N lat, 95°53′W long) and in Whitemouth River, the northernmost limit of range (49°57′N lat, 95°59′W long).

Biology The biology of the hornyhead chub has been rather thoroughly documented as a result of studies in the eastern United States (Lachner 1952). Although studies have been conducted in Ontario waters, none have been published. Of particular interest is the work of A. H. Carter, whose reports provided much of the following information. His work was undertaken during the summers of 1934–1939, in the Maitland and Bayfield rivers, Lake Huron drainage, Ont., while he was engaged in undergraduate and graduate studies at the University of Toronto.

Spawning takes place in the spring of the year, probably when water temperatures reach about 65° F (23.9° C). Nests of stones and pebbles are built by the males on a fine gravel or pebble bottom, often below a riffle, and in relatively shallow water. The depth of water is such that the top of a completed nest is 6–18 inches below the surface. Nest building is usually begun after May 15. As construction progresses, females may approach the nest and be enticed or driven over it by the male. Spawning takes place in a few seconds and the female moves quickly downstream. The released eggs settle among the stones and the male continues to add more stones to the nest, thus ensuring additional protection for the eggs. The nest building consists of carrying stones in his mouth or rolling or pushing them with lips and snout. Both Carter (1940) and Lachner (1952) suggested that females probably retained in the ovaries a maximum of about 1000 eggs. Lachner made egg counts for four females of 80–89 mm standard length and found the egg number to range from 460 to 725. The total egg complement is not deposited in one nest at one time, since at each spawning an individual female deposits only some of the total number, that is, only those that are ripe. Carter believed that as many as 10 females spawned in one nest under observation. The nest mound increases in size as more stones are added by the male after successive spawnings. The sizes of nests are irregular and vary from 12 inches (305 mm) to 36 inches (914 mm) across, and from 24 inches (610 mm) to 36 inches (914 mm) long (with current), and from 2 to 6 inches (51–152 mm) deep, according to Hubbs and Cooper (1936).

The nesting sites may be used as spawning grounds by other species of minnows (Lachner and others), but Carter did not observe this phenomenon. However, he did observe that other species, especially centrarchids, nested nearby. *Notropis cornutus* and *N. rubellus* are among the species that have been reported to use the nests of *Nocomis* spp., and do so while the *Nocomis* are also using the nest.

Information on the rate of development is apparently not available, especially in Ontario waters, but there is some data to indicate the size range (standard length) from young-of-the-year to 4-year-olds: age 0 (24–36 mm); age 1 (44–58 mm); age 2 (64–83 mm); age 3 (86–100 mm); age 4 (131 mm).

Carter concluded that males grow more rapidly than females, reach a larger size, and that age 4 is the maximum age attained for either sex. The maximum size attained in Carter's study area was 6.1 inches (155 mm) for males and 4.4 inches (112 mm) for females. The largest specimen in the Royal Ontario Museum collections is a male, 6.3 inches (161 mm) in total length, from the Bayfield River, Lake Huron drainage, Ont.

The hornyhead chub seems to prefer clear, slow-moving, gravelly streams, more often in the tributaries of large rivers, and the young seek out areas having aquatic vegetation.

The food consists of both plant and animal tissues, herbivorous material being more important in the diet of young fish. Stomachs were sometimes full of filamentous algae, but diatoms were also taken. Young fish also eat cladocerans and aquatic insect larvae, such as chironomids. As they grow larger, snails, aquatic insect larvae (including caddisflies), annelids, crayfish, and fish assume greater importance, especially snails. Snails become quite important in the diet of 1-year-old fish and older.

We have no information on predators on the species in our waters although young chub must undoubtedly fall prey to such centrarchids as rock and smallmouth basses, when present.

Carter noted that the hornyhead chubs in his study area were relatively free of parasites and possessed only a few black-spot parasites, (*Neascus* sp.).

Hoffman (1967) listed the following parasites from the hornyhead chub in North American waters: Protozoa (2), Trematoda (9), Cestoda (1), Nematoda (2), Acanthocephala (2).

Relation to man This chub was highly regarded in the northern United States as a bait fish, especially for northern pike, because it attained a large size, was hardy, and could withstand the rough treatment afforded by storage tanks and minnow pails (Dobie et al. 1956; Harlan and Speaker 1969). Trautman (1957) noted that it was once widespread in Ohio and was widely used for food and bait, but that by 1950 it existed only in widely scattered relict populations.

In Canada, it is not an important bait species primarily because it has such a limited distribution and it is probably much less common now than formerly. It is seldom, if ever, distinguished by fishermen from the creek chub, which is much more common.

Nomenclature

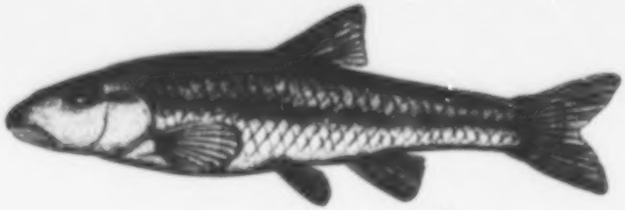
Semotilus biguttatus	— Kirtland 1841b: 344 (type locality Yellow Creek, tributary of Mahoning, Ohio)
Hybopsis kentuckiensis (Rafinesque)	— Jordan and Evermann 1896–1900: 322
Nocomis biguttatus Kirtland	— Hubbs 1926: 28
Nocomis kentuckiensis (Rafinesque)	— Jordan, Evermann, and Clark 1930: 137
Hybopsis biguttata (Kirtland)	— Scott 1967: 64

Etymology *Nocomis* — an Indian name, applied by Girard to a group of fishes; *biguttatus* — two-spotted.

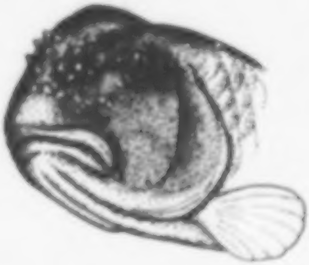
Common names Hornyhead chub. French common name: *tête à taches rouges*.

RIVER CHUB

Nocomis micropogon (Cope)



Description Body stout, heavy anteriorly, elongate, average length about 4 inches (102 mm), deepest in front of pelvic fins, greatest body depth 18.5–24.6% of total length.



Head bluntly triangular, and wide, its length 20.8–24.6% of total length; eye diameter 15.6–30.0% of head length, smallest in large specimens; snout bluntly rounded, long, 36.3–50.0% of head length, slightly protruding beyond upper lip when mouth closed; interorbital width 35.0–45.4% of head width; mouth moderate and nearly terminal, the snout slightly projecting, lower lip included by upper lip, a distinct terminal barbel at the angle of upper and lower jaw, upper jaw not reaching anterior margin of eye; pharyngeal teeth usually 4–4, sometimes 3–4. Fins: dorsal 1, opaque, its origin over pelvic fin origin, rays 8(19), rarely 7(1); caudal with shallow fork, tips rounded; anal 1, its origin behind dorsal insertion, rays 7(19), rarely 8(1); pelvics small, origin under dorsal fin origin, rays 8(20); pectorals well developed, rounded, rays usually 16(10), or 17(7), sometimes 15(3). Scales cycloid, large, margins somewhat accentuated with melanophores, the angle subtended by scale radii greater than 90°, usually 95°–105°; lateral line complete, nearly straight, only slightly decurved, scales 39–43. Peritoneum uniformly brown or black, with darker speckles; intestine short. Vertebrae 38 or 39.

Nuptial tubercles well developed and large, usually less than 40, on anterior part of head, from tip of snout to anterior edge of orbit but not extending dorsally to the midinterorbital region; a pronounced swelling develops on top of head of large males, in occipital and interorbital region.

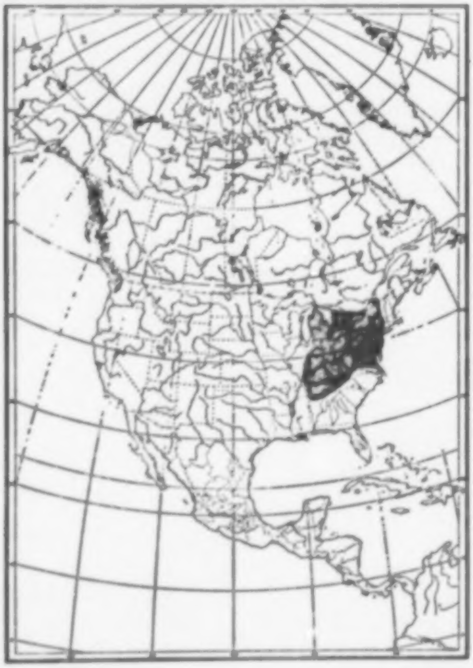
Colour Overall colour olive-brown on back, silvery on sides, becoming creamy white below. Lateral band inconspicuous and vague in life; well defined on young, when preserved, to a length of about 2.5 inches (64 mm), becoming less conspicuous on larger specimens. Breeding males without a red postocular spot, but large males (not small ones) may have a rosy hue on flanks, and the dorsal and caudal fins are olive or yellowish.

Systematic notes Members of this genus were placed in the genus *Hybopsis* in many recent publications, in particular the

1960 issue of the American Fisheries Society's *Checklist of Common and Scientific Names* but the genus *Nocomis* was re-instated in the 1970 issue of the checklist.

Prior to 1925, hornyhead and river chubs were not recognized as distinct species and hence the early literature is confusing (Hubbs 1926; Trautman 1957).

See Lachner (1952) and, in particular, Lachner and Jenkins (1967) for a discussion of the systematics of fishes in the genus *Nocomis*. Hybridization has been noted with other species, such as *Notropis cornutus* (Trautman 1957), but hybrids between species of the genus *Nocomis* are rare. A discussion of associated species on river chub nests was given by Reighard (1943).



Distribution The river chub has a smaller general range than the hornyhead chub. It occurs in clear creeks and rivers from Lake Champlain and the Lake Ontario basin, west through southern Michigan and Indiana in the Wabash system; south on the Atlantic slope from the Susquehanna River in New York to Virginia, North Carolina, Tennessee, and Georgia. Scattered records from Big Bend tributaries in Alabama and Tennessee. (For discussion of distribution in United States waters, *see* Lachner and Jenkins 1967.)

In Canada the species is found only in the drainage system of Lake Ontario from the Humber River westward, Lake Erie tributaries, including the Grand River and Catfish Creek, Lake St. Clair tributaries, including the Thames River and Medway Creek, and southern Lake Huron tributaries, including the Ausable, Maitland, and Saugeen rivers.

Biology As was noted for the hornyhead chub, the biology of this and related members of the genus has been rather thoroughly documented by workers in the United States, in particular by Reighard (1943), Lachner (1952), and Lachner and Jenkins (1967). Unfortunately, few observations on Ontario populations have been reported, but spawning behaviour in general is similar to that given for the hornyhead chub as reported for Ontario streams by Carter (1940) (*see* hornyhead chub). Spawning occurs in gravelly streams in spring, over a nest of stones built by the male who first excavates a channel or depression, removes all sand and fine gravel, and then fills the depression with newly gathered stones. Reighard reported that each individual spawning act took place in a shallow trough constructed on the nest pile for the purpose by the male, and immediately filled in with small stones and pebbles on completion of the spawning act.

As in the case of the hornyhead chub, each female probably deposits 1000 eggs or fewer. Lachner (1952) reported egg counts of 400–625 in four females ranging in standard length from 92 to 100 mm.

Dimensions of nests (the stone piles) in Michigan streams were given by Reighard and were of the order of 36 inches (914 mm) across (across current), and 48 inches (1219 mm) in long axis (with current). The use of the nests as spawning grounds by other species was also discussed by Reighard, and we believe that *Notropis cornutus* and *N. ru-*

bellus at least may use river chub nests for spawning sites.

Information on rate of development is not available but the following figures on standard lengths at various ages were gathered for specimens from Lake Huron drainage [illegible] 0 (44–49 mm); age 1 (55–74 mm); [illegible] (76–94 mm); age 3 (104–116 mm); [illegible] (131–148 mm); age 5 (148–162 mm).

The sample sizes were small but it is evident that the river chub grows faster, attains a larger size, and may live at least 1 year longer than the hornyhead chub. The males attain a larger size than females; the largest specimen in the ROM collection is a male, 8.3 inches (210 mm) total length, from the Nith River, Lake Erie drainage.

The river chub frequents large gravel-bottomed or rocky rivers, rather than creeks, but it requires clean, clear water. It may be absent from much of its former range in western Lake Ontario tributaries.

The diet of this large chub is not well known and we assume that it is similar to that of the hornyhead. It possibly consumes algae and zooplankton when young, taking progressively larger items, such as aquatic insect larvae, and other aquatic invertebrates, such as snails, crayfish, and possibly some fish. No food studies have been conducted on Ontario populations.

Bangham and Hunter (1939) examined 18 specimens of river chub from the east end of Lake Erie and found 9 fish with parasites, identified as trematodes *Neascus vancleavei*, *Neascus* sp., and a nematode *Agamonema* sp. Hoffman (1967) listed 3 trematodes (*Gyrodactylus* sp., and the larval forms of *Neascus* sp., and *Posthodiplostomum minimum*) from river chub in North American waters.

Relation to man The river chub was possibly as important a bait minnow in United States waters as the hornyhead chub but both are now less abundant because of watershed deterioration. It is a large chub, growing to over 8 inches (203 mm) long even in Ontario waters, and was probably used for food here as it was in parts of the United States, but we have no supporting data or observations. When used as a bait species, it is probably not distinguished by dealers and anglers from the more common creek chub.

Nomenclature

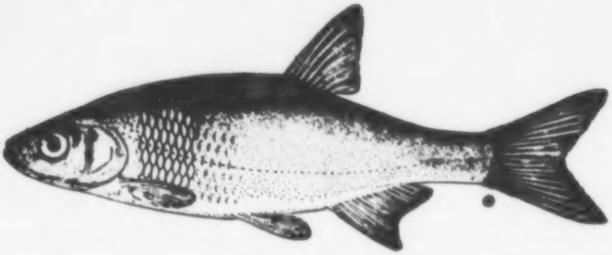
Ceratichthys micropogon	— Cope 1864: 277 (type locality Conestoga River, Pa.)
Nocomis micropogon (Cope)	— Hubbs 1926: 29
Hybopsis micropogon (Cope)	— Scott 1967: 64

Etymology *Nocomis* — Indian name applied by Girard to group of fishes; *micropogon* — small; beard.

Common names River chub, eastern [illegible] chub, crested chub. French common name: *méné bâton*.

GOLDEN SHINER

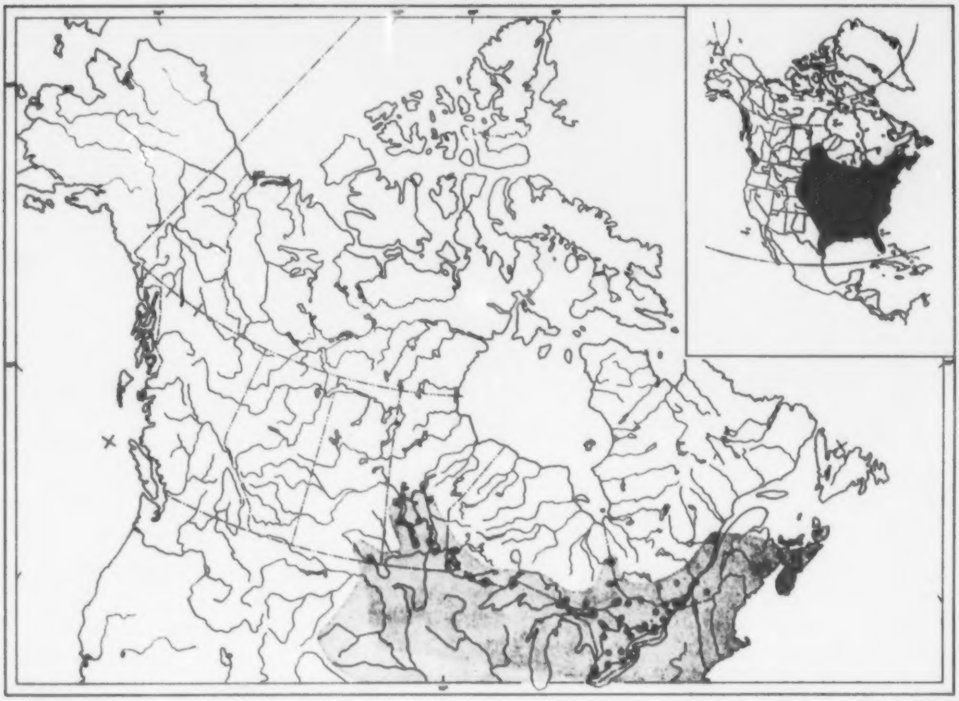
Notemigonus crysoleucas (Mitchill)



Description Body deep, strongly compressed laterally, average length 3–5 inches (76–127 mm) depending on locality, greatest body depth in front of pelvic fins, 17.4–26.4% of total length; a pronounced fleshy keel between pelvic fins and anal origin, the scales extend to but do not pass over this keel, which is apparent on fish as small as 25 mm; caudal peduncle relatively long and slender. Head triangular, small, its length 17.1–20.0% of total length; eye moderate, its diameter 23.9–33.3% of head length; snout relatively short, 26.3–34.4% of head length; interorbital arched, its width 33.3–45.4% of head length; mouth oblique, opening narrow, lower jaw projecting, upper jaw extending to a point below nostril; pharyngeal teeth 0,5–5,0, hooked, with distinct grinding surface. Fins: dorsal 1, its origin distinctly posterior to pelvic fin origin, posterior edge straight or slightly falcate, rays usually 8(48), rarely 7(2), or 9(1); caudal distinctly forked, lobes pointed; anal 1, origin approximately below dorsal fin insertion, posterior edge falcate, rays highly variable, usually 12–14 in Quebec, New Brunswick, and Nova Scotia, 12 or 13 (rarely 11), in Ontario, Manitoba, and Saskatchewan, but throughout its total range, rays vary from 8–19 (*see* section on *Systematic notes*); pelvics originate distinctly in advance of dorsal fin origin, rays usually 9(34), rarely 8(2); pelvic axillary process present or absent; pectorals rather short, never reaching pelvic fin origin, rays 16(17), 17(18), or 18(1). Scales cycloid, persistent; lateral line complete, and characteristically decurved, often accentuated with pigmentation around the pores, lateral line scales 44–54. Peritoneum dusky; intestine short, body length or slightly longer, 1.0–1.3 (Bensley 1915). Vertebrae 37(5), 38(10), or 39(1).

Colour Overall colouration golden. On adults, the back is olive-green to dark brown and sides have distinct brassy colouration. The fins are yellowish; young fish do not have the strong yellowish colouration of the adult but are silvery with transparent fins, and have a strongly pigmented and conspicuous lateral band, particularly obvious on preserved specimens. The lateral band is apparent on preserved specimens to lengths of about 4 inches (102 mm) but becomes increasingly vague and ill defined with increase in length. Fish (1932) noted that young, 18 mm long, were heavily pigmented.

Systematic notes The high degree of variability, particularly in anal fin ray number, of the golden shiner throughout its range has long been recognized. Hubbs (1921b) first drew attention to the regional nature of the variability. This was later interpreted by Schultz (1926) as clinal. The total range in anal ray counts was shown by him to be



8–19. The range in Canada is at least 10–15, as shown in the following table:

Locality	Anal rays 10	11	12	13	14	15
N.S.	–	–	1	5	4	–
N.B.	–	–	4	4	2	–
Que.	–	–	1	2	7	–
Ont.	–	1	7	8	–	–
Sask.	–	–	4	2	–	–
"Ont., Canada, vicinity"	1	2	39	20	1	1

Some authorities recognized subspecies (Hubbs and Lagler 1958) although others did not (Bailey and Allum 1962). We are not recognizing subspecies in this work, but three subspecies have been described: the typical one *N. c. crysoleucas*, the eastern golden shiner, which occurs in the Maritime Provinces and Quebec to the eastern Ontario basin, south along the Atlantic coast to Virginia; *N. c. auratus*, the western golden shiner, which occurs from the Lake Ontario basin west through all the Great Lakes to Saskatchewan, south to Arkansas and Oklahoma; and *N. c. bosci*, the southern golden shiner of the Atlantic drainage of the Carolinas, south and west to the Gulf states drainages.

Distribution On the east coast of North America from the Maritime Provinces south to Florida; west to the Dakotas and Texas (Hubbs and Cooper 1936). Because of its wide use as bait, it has been introduced into many parts of the western United States to which it is not native. *See* Miller (1952) for details.

In Canada the golden shiner occurs widely in Nova Scotia, where Livingstone (1953) stated it was the most common minnow, occurring in all regions except isolated areas of the Cape Breton Plateau and Digby Neck. In New Brunswick it is present in many of the major river systems (for details *see* Scott and

Crossman 1959), probably resulting from invasion from coastal areas. In Quebec it ranges from Gaspé, southwest through the eastern townships to Lake Champlain; on the north shore of the St. Lawrence it extends from near Escoumains southwest in the St. Lawrence drainage, north to Lake Abitibi. In Ontario it is found in all the Great Lakes drainages, north to Lake Abitibi in the James Bay drainage. In Manitoba, it is found frequently at the mouths of rivers and on sandy beaches of Lake Winnipeg, extending north to Mukutawa River (53°09′N lat, 97°25′W long), its northern limit of range in North America (Keleher 1956); Keleher and Kooyman (1957) reported collections from the Whiteshell Forest Reserve, Lake Manitoba, and a tributary of Lake Winnipegosis. In Saskatchewan, Atton and Johnson (1955) recorded a collection in the Souris River at Oxbow on July 27, 1954, the first record of the species in that province.

It has been introduced into Prince Edward Island, but is absent from Newfoundland, and the provinces west of Saskatchewan.

Biology The time of spawning and rate of growth of the golden shiner in the northern United States, particularly in New York and Michigan, have received considerable attention, but few Canadian studies have been undertaken and even fewer published.

Spawning has been observed in Michigan from June to August and in New York from May to July, suggesting a prolonged spawning period. In eastern Ontario, in the Gananoque River of the St. Lawrence drainage area, Toner (1943) considered spawning about to commence as early as June 11, and in Nova Scotia, Smith (1939) considered that golden shiners were in the midst of spawning on August 3. In spite of the paucity of direct observations, it is reasonable to assume that spawning in many parts of the Canadian range takes place about the same time as that described for northern New York or Michigan populations; undoubtedly the precise dates of spawning are different in different parts of the Canadian range.

The adhesive eggs are deposited over filamentous algae. Sometimes rooted aquatic plants will serve, but aquatic vegetation is essential for spawning (Cooper 1935, 1936b). Spawning commences when water temperature is about 68° F (20° C) according to Dobie et al. (1956). The eggs, each measuring 1 mm in diameter, are scattered and abandoned by the spawning fish. Deviation from this apparently normal behaviour was reported by Kramer and Smith (1960a), who noted that golden shiners used active largemouth bass nests for spawning in Lake George, Minn., even while the male bass was guarding the nest.

Despite the active interest in pond culturing this species, there seems to be only minimal information on breeding behaviour, embryology, and development. The 18 mm stage was described and illustrated by Fish (1932) for Lake Erie, and Mansueti and Hardy (1967) published information on prejuvenile stages in the Chesapeake Bay region.

The rate of growth varies greatly from place to place depending on temperature and availability of food and it is to be expected that considerable variation would be exhibited throughout the Canadian range. Faster rates of growth would be expected in southern Ontario, in Lake Erie, for example, than in Lake Abitibi, although growth data have not been published for either region. Dymond and Hart (1927) did note that the largest specimen caught in Lake Abitibi was 2.5 inches (64 mm) long, although we have specimens from Lake Erie measuring 8 inches (203 mm) long.

Age was determined, using scales, by Cooper (1936b), but Smith (1939) was unable to age Nova Scotia specimens by this method. On the basis of Michigan studies, Cooper noted that a length of about 3 inches (76 mm) was reached during the second summer, 4 inches (102 mm) during the third, 4.5 inches (114 mm) during the fourth, and 5.5 inches (140 mm) during the fifth summer. In some nutrient-rich waters, this shiner attained 3 inches (76 mm) in length in its first summer. Maturity is reached usually at lengths of 2.5–3.5 inches (64–89 mm), usually in their second summer, but maturity will be delayed until their third summer in regions of slow growth. The oldest fish recorded by Cooper was in its eighth summer. A fish, 10.5 inches (267 mm) long, weighing 12 ounces (340 g) was reported by Trautman (1957). The largest Canadian specimen known to us is one 9.2 inches (234 mm) long taken near Granby, Que.

The golden shiner prefers clear, weedy, quiet, waters, with extensive shallow areas. It is a lake species rather than a river form, an actively swimming fish that moves in schools, off bottom, over wide areas.

Food studies of the golden shiner have been conducted by Keast and Webb (1966) in Lake Opinicon, Ont., where the main foods were found to be as follows: Cladocera 20–90% by volume (depending on the month), flying insects 20%, chironomid pupae 10–30%, and filamentous algae (important in late summer); small numbers of dragonfly nymphs, beetles, and water mites may also be eaten. In another lake, molluscs were consumed. In general, however, the diet was consistent from lake to lake and there was little significant difference in the diet of adults and young. They concluded that the species was a midwater and surface feeder.

The golden shiner is a most important forage fish and figures prominently in the diet during the early life of many of our game fishes, such as largemouth bass and muskellunge.

Bangham and Hunter (1939) found trematodes, *Neascus* sp.; nematodes, *Agamonema* sp., protozoans and myxosporidians in specimens examined from Lake Erie Bangham and Venard (1946) examined seven specimens in lakes in Algonquin Park and found no parasites. Four golden shiners from Lily Lake on Manitoulin Island were examined by Bangham (1955) and all were infected with trematodes *Diplostomulum* sp., one with Gyrodactyloidea, and one with the nematode *Contracaecum brachyurum*. In an examination of this species from a commercial bait hatchery in Illinois, Summerfelt (1964) found a microsporidian (sporozoan) parasite in the ovaries of the golden shiner, and suggested that the presence of this parasite could be of importance to the bait industry since it is known to reduce fecundity.

A new species of acanthocephalan, *Neoechinorhynchus notemigoni*, was described from the intestine of golden shiners caught in Lake Ontario by Dechtiar (1967a).

Hoffman (1967) listed the following parasites from this species in North American waters: protozoans (2), trematodes (15), cestodes (3), nematodes (3), acanthocephalans (3), leeches (3), and crustaceans (3).

Relation to man The golden shiner may well be the most popular of all bait fishes in North America. Its use as a bait or forage minnow is not restricted to its native range in eastern and central North America for it has been introduced to many waters in the western part of the continent as well (Miller 1952).

In Nova Scotia, New Brunswick and parts of Quebec, it is the most common bait fish offered for sale. In Ontario it is also a popular bait fish in some areas but does not dominate the market as it does in the east.

The golden shiner has been cultivated successfully in ponds for many years in various parts of the United States from Michigan to Mississippi. Fish are pond cultured for sale as bait, or by fish hatcheries as food for pond-cultured bass, especially the largemouth (Regier 1963a). With the increase in demand for live bait and rapid destruction of natural water areas by pollution and careless construction practices, the attractiveness of pond culturing bait minnows increases. And few species offer greater promise than the golden shiner. In a review of bait fish production in ponds in New York, Forney (1957) noted that the yield from 10 fertilized ponds for a 2-year period averaged 420 pounds/acre. For detailed information on pond cultivation of golden shiners, *see* Cooper (1936b), Dobie et al. (1956), and Forney (1957).

Nomenclature

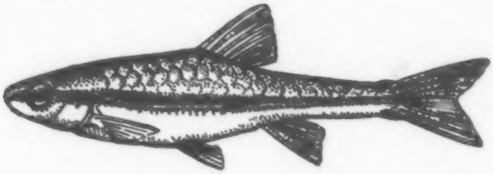
Cyprinus Crysoleucas — Mitchill 1814: 23 (type locality New York)
Cyprinus (*Leuciscus*) *chrysoleucas* (Mitchill?) — Richardson 1836: 122
Leuciscus chrysoleucas — Perley 1852: 193
Leucosomus Americanus Storer — Adams 1873: 305 (probably in error for *Leuciscus Americanus*)
Notemigonus chrysoleucas (Mitchill) — Kendall 1895: 54
Notemigonus chrysoleucas Mitchill — Cox 1896b: 65
Abramis crysoleucas (Mitchill) — Jordan and Evermann 1896–1900: 250
Notemigonus crysoleucas (Mitchill) — Dymond and Hart 1927: 15

Etymology *Notemigonus* — back; half; angle; the back being almost carinated; *crysoleucas* — gold; white.

Common names Golden shiner, roach, bream, butterfish, eastern golden shiner, American roach, American bream, sunfish, dace, bitterhead, chub, gudgeon, young shad, windfish, goldfish. French common name: *chatte de l'est.*

PUGNOSE SHINER

Notropis anogenus Forbes



Description Body fragile, slender, small, 1.5–2.0 inches (38–51 mm) long, somewhat compressed laterally, especially the posterior portion, body depth 16.6–22.0% of total length. Head length 18.9–21.6% of total length; eye diameter relatively large, 26.6–37.5% of head length; snout length somewhat smaller than eye diameter, 23.5–31.2% of head length; interorbital wide, its width 29.4–42.8% of head length; mouth extremely small, terminal or nearly so, oblique, upper jaw extending backward only to below nostrils; pharyngeal teeth 0,4–4,0, slightly hooked at tip. Fins: all transparent, dorsal 1, rays usually 8(19), occasionally 7(1); caudal forked; anal 1, rays usually 8(19), occasionally 7(1); pelvics originate slightly in advance of dorsal fin origin, rays 8(19), rarely 7(1); pectorals well developed, rays usually 12(13), occasionally 11(4) or 13(3). Scales cycloid, large, 34–38 in lateral line; lateral line complete. Peritoneum dark. Vertebrae 32–36.

Nuptial tubercles, not observed in specimens from our region, but Trautman (1957) noted that breeding males had microscopic tubercles on top of head, and dorsal surfaces of pectoral rays and sometimes pelvic rays were thickened and roughened.

Colour Overall colouration silvery with pale yellow or straw-coloured tints on back and silvery below. All fins are transparent. There is a distinct, dark lateral band that extends around the snout (but not on central part of upper jaw), including the lower jaw (chin pigmented), through the eye and thence midlaterally to end of caudal peduncle, but weakening posteriorly; a small dark spot is evident at caudal base.

Systematic notes Bailey (1959) noted that the species was described by Forbes (1885) from a collection of 24 specimens collected in the Fox River at McHenry in the lake district of northeastern Illinois. Of the 8 specimens still in the collection of the Illinois State Natural History Survey, 6 are *Notropis anogenus* and 2 *Notropis heterodon*, which emphasizes the similarity of these two species.

Distribution The pugnose shiner is restricted to the Great Lakes basin, particularly in the United States. It is known to occur in waters of the following states: New York, Ohio (formerly), Michigan, Indiana, Illinois, Wisconsin, Minnesota, and North Dakota.

In Canada it has been reported to occur only in two regions of Ontario: at the extreme eastern outflow of Lake Ontario at Gananoque, and in western Lake Erie at Rondeau Bay and the ponds on the eastern side of Long Point. It has been reported from the United States, but not the Canadian, waters of Lake St. Clair. The kind of habitat required, i.e., clear, weedy lakes and quiet streams with clean sand or marl bottoms, and the extreme sensitivity to turbidity, leads us to conclude that it has a diminishing range in Ontario. It seems probable that it once occurred in suitable waters along the north shores of lakes Ontario and Erie, between the two widely separated areas where it lives at present. Trautman (1957) noted that it has completely disappeared from Ohio waters. *See* Bailey (1959) for a comprehensive review of the distribution and taxonomy of the species. He also suggested that increased agricultural use of land and water has had a detrimental effect on its occurrence.

Biology Few critical studies of this species have been made, none in Canada. It presumably spawns in the spring, probably in June in Ontario waters. A small collection made at Point Pelee, Lake Erie, on June 13, 1941, contained one female with a few large eggs, suggesting that she was partly spent and that spawning was in progress at time of capture.

The extremely small mouth must restrict its diet to minute plant and animal organisms, and organic detritus, but actual observations are not available.

According to Hoffman (1967) the pugnose shiner is infected with only two species of Protozoa, and no other parasites are recorded. There are no records of parasitic infestation in Canadian populations.

Relation to man The pugnose shiner is of no known significance in the economy of our waters because of its fragility, small size, and restricted distribution. It seems probable that its Ontario range is being continually reduced by environmental change.

Nomenclature

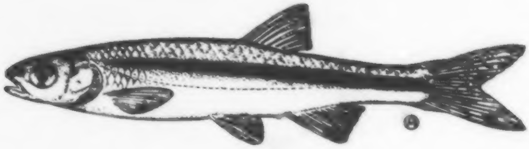
Notropis anogenus	— Forbes 1885: 138 (type locality Fox River, McHenry, Ill.)
Hybopsis anogenus (Forbes)	— Jordan, Evermann, and Clark 1930: 136

Etymology *Notropis* — back; keel; *anogenus* — without; chin.

Common names Pugnose shiner. French common name: *méné camus*.

EMERALD SHINER

Notropis atherinoides Rafinesque



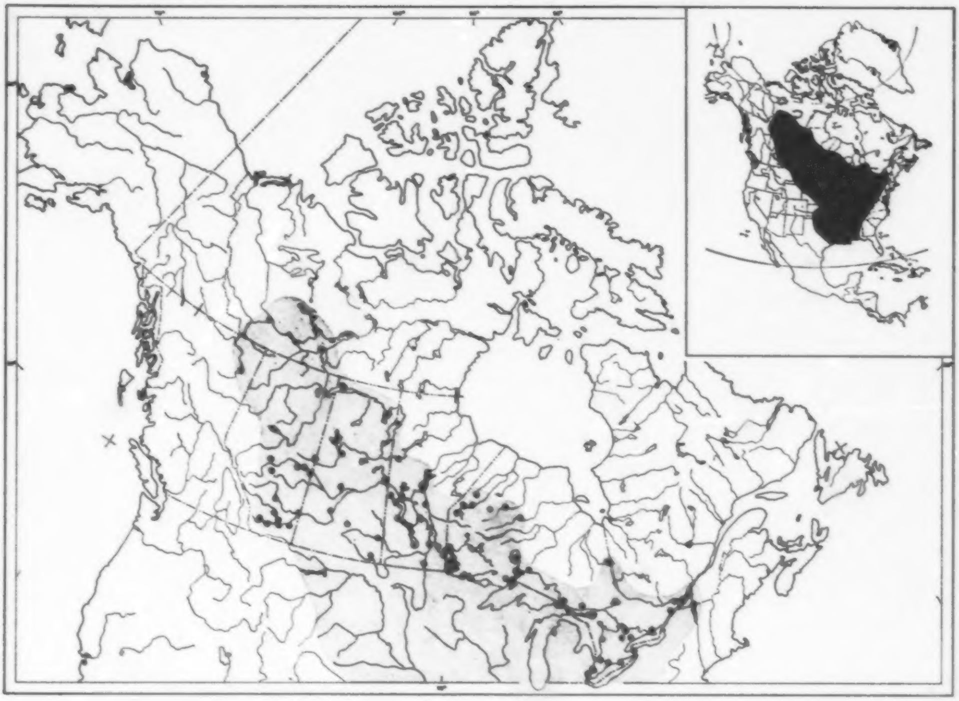
Description Body slender, even fragile, elongate, averaging 2–3 inches (51–76 mm) long, strongly compressed laterally, its greatest depth 14.2–20.0% of total length. Head generally triangular, its length 17.2–21.4% of total length; eye relatively large, its diameter 26.6–34.6% of head length; snout bluntly pointed, its length about equal to eye diameter, 26.6–33.3% of head length; interorbital width also about equal to eye diameter, 26.6–34.6% of head length; mouth relatively large, terminal, but gape extends only to a point below nostrils; pharyngeal teeth sturdy, hooked, usually 2,4–4,2, occasionally 1,4–4,2 or 2,4–3,2. Fins: generally clear; dorsal 1, its origin clearly posterior to pelvic origin, rays usually 8(72), rarely 7(1 only, from Lake Winnipeg); caudal forked; anal 1, rays usually 11(56), occasionally 10(21), or 12(16), but rarely 13(1); pelvics originating distinctly in advance of dorsal origin, rays usually 8(56), occasionally 9(6), small pelvic axillary process present; pectorals usually 14–16, rarely 13 or 17. Scales cycloid, deciduous, of moderate size, 38–43 in lateral line; lateral line complete. Peritoneum silvery and speckled. Vertebrae 38–41, usually 39 or 40.

Nuptial tubercles on breeding males very small, restricted to upper surface of pectoral fins.

Colour Overall colouration silvery, with blue-green or green iridescence on the back, silvery on sides and silvery white below. The young are rather translucent. The scales are lost even with the most careful handling, resulting in a dark blue or blue-green appearance. The fins are clear and no brilliant colours are displayed during spawning. Preserved specimens exhibit a characteristic dark lateral band which is darkest posteriorly becoming vague and ill-defined anteriorly, and the melanophores are restricted mainly to the region above the lateral line.

Systematic notes At least two subspecies of emerald shiner have been said to occur in the Great Lakes region (Hubbs and Lagler 1964): the typical subspecies, the so-called river emerald shiner, *N. a. atherinoides*, (the form said to occur through most of Canada) and the lake emerald shiner, *N. a. acutus*, which is said to occur at least in lakes Huron and Superior. However, some recent authors (Bailey and Allum 1962; Flittner 1964) indicated that the species is highly variable in meristic and morphometric values throughout its range (an observation with which we concur) and concluded that, since variations in certain characters such as some body proportions and vertebral numbers exhibited clinal variations, the recognition of subspecies at this state of our knowledge was unwarranted. The following vertebrae counts from three Canadian regions will serve only to illustrate the need for further study.

	No. vertebrae			
	38	39	40	41
Vaudreuil, Que.	3	5	4	–
L. Erie, Ont.	–	6	5	1
L. Winnipeg, Man.	–	2	7	–



Distribution The emerald shiner occurs in large open lakes and rivers in many parts of Canada, and in the Mississippi valley south to the Gulf coast in Alabama and in Trinity River, Texas.

In Canada, the species inhabits the upper St. Lawrence River in Quebec, at least to Trois Rivières, and Lake Champlain, and west through all of the Great Lakes. North in Ontario the range extends at least to lakes Attawapiskat and Abitibi, and to the headwaters of the Severn River. It is common west through Manitoba, Saskatchewan, Alberta, and British Columbia. Recorded also from tributaries of the Mackenzie River south from the junction of the Mackenzie and Liard rivers, including Fort Nelson River in British Columbia, but has not been recorded from the Peace River (McPhail and Lindsey 1970).

It has not been reported from the Maritime Provinces, nor from Newfoundland.

Biology The emerald shiner is of considerable importance to the Canadian freshwater fishery but few, if any, definitive studies have been conducted on any aspect of its biology in the Canadian range. Hence, much of the following information is derived from studies in northern United States waters.

Factual reports of spawning in Canadian waters are lacking but Dymond (1926) observed females distended with nearly ripe eggs when caught on July 12, 1922, in the Sturgeon River, Lake Nipigon, Ont. Similar observations suggest that the emerald shiner spawns in late spring or early summer in most Canadian localities, probably in midwater. Indirect evidence suggests a prolonged spawning season since Fish (1932) noted that 1–500 larvae were caught in Lake Erie in every tow made between July 2 and August 30, 1929. Langlois (1954) also suggested that spawning continued in Lake Erie until at least mid-August. Some authors stated that spawning occurred at 75.2° F (24° C), and that hatching occurred in less than 24 hours. Flittner (1964) reported that hatching occurred 24–32 hours after fertilization, at a size of 4.0 mm; in 30 hours fry were 4.9 mm long; in 90–96 hours, 6.1 mm; and in 11 days, 8.9 mm. Fish (1932) described and illustrated larval stages from 4.9 to 13.5 mm.

In Lake Simcoe, Ont., McCrimmon (1956) reported that young-of-the-year averaged nearly 2 inches (51 mm) long and a weight of 0.3 ounces by mid-November, and by the following autumn were 3 inches (76 mm) long and weighed nearly 1 ounce (28.0 g). He noted that few survived until the autumn of the third year, but some were collected, 3.3 inches (84 mm) long, weighing 1.2 ounces (33.6 g). McCrimmon also presented a growth curve.

It appears that emerald shiners do not usually live beyond 3 years; Fuchs (1967) had only four specimens beyond age 3, but Canadian data are lacking. Emerald shiners may attain total length of about 4 inches (102 mm). Specimens in the ROM collections from Rainy River region in Ontario (a male) measured about 4 inches (103 mm) and from Lake Athabasca, Sask. (a female), about 4 inches (101 mm) total length.

The emerald shiner is a pelagic or open-water species, inhabiting lakes or large rivers. It is a schooling species, staying offshore during summer months, usually near the surface, but moving inshore in autumn, sometimes aggregating off docks, piers, and river mouths in countless numbers, but apparently with less frequency in the Great Lakes and Lake Simcoe than in former years. These large schools in inshore waters are usually composed of young-of-the-year. As the season advances they move into deeper water for overwintering. In early spring they move into surface waters at night, dropping down to deeper waters during the day.

Available evidence suggests that emerald shiner populations fluctuate widely in abundance from year to year. For example, routine sampling by seine in the vicinity of Port Dover, Lake Erie, Ont., during 1946–49, using comparable methods, yielded the following numbers of emerald shiners: 1946, 6307; 1947, 541; 1948, 1225; 1949, 300. Periodically biologists and commercial fishermen become concerned with the relative scarcity of emerald shiners in Lake Erie, but conversations with retired fishermen lead one to conclude that periods of scarcity followed by great abundance have been characteristic of the populations for over 50 years.

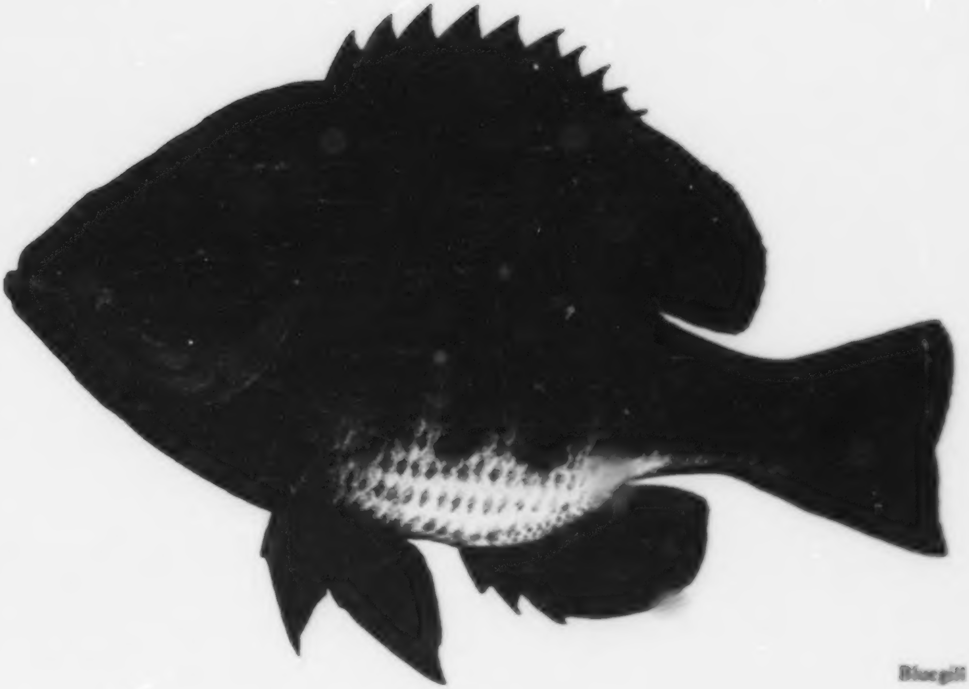
It is an important forage species and since it is not a commercial nor a sport fish, we do not have regularly gathered catch records, but some method should be devised for monitoring the state of the population from year to year.

In South Dakota, Fuchs (1967) concluded that high mortality rates caused drastic changes in age-class structure of populations. He also noted that during the second and third year of life males had a higher mortality rate than females.

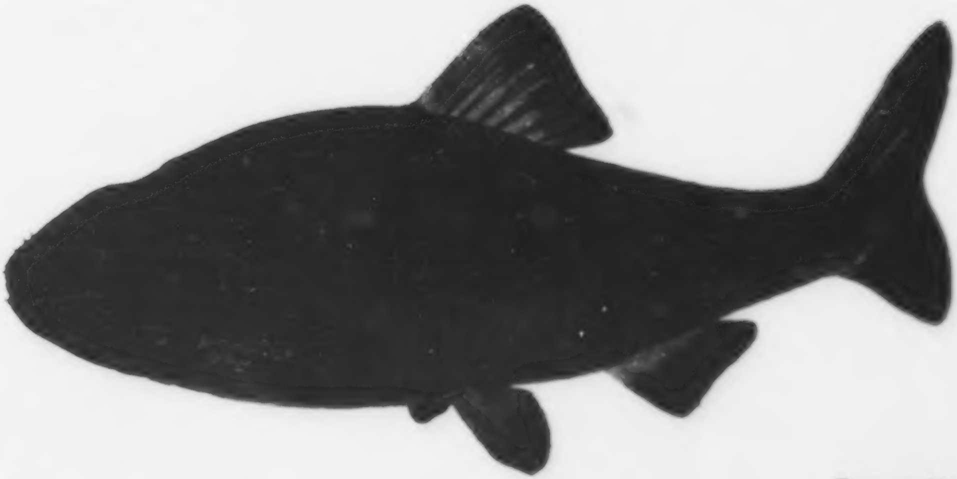
Emerald shiners feed heavily on microcrustaceans, some midge larvae, and algae, and tend to move with this planktonic food supply toward the surface at dusk, and descend again at daybreak. Evidence gathered by Gray (1942) in Lake Erie during December indicated that the evening feeding period was most important. He found *Diaptomus*, *Daphnia*, *Cyclops*, and *Bosmina* all important in the diet but at different times of the day, and concluded that size selection of prey was important, but that the pattern of vertical migration of the prey may also be significant.

In South Dakota, Fuchs found that blue-green algae and ciliated Protozoa were important in the diet up to the 1-inch (25-mm) length stage, then green algae was consumed in addition, and at 1.6–1.8 inches (41–45 mm) *Daphnia* became increasingly important, but *Leptodora* and *Diaptomus* were also taken, as well as small quantities of blue-green algae and diatoms. In the diet of adults, zooplankton (*Daphnia*, *Diaptomus*, and *Leptodora*) was of greatest importance, followed by insects (Diptera).

So many creatures prey upon emerald shiners it would be impossible to list them all. In Lake Erie, Langlois (1954), reported a count of 373 emerald shiners in the stomach of a burbot caught in October. During the peak of Lake Erie blue pike fishing in the



Bluegill



Common shiner

1950's, millions of pounds of fall-caught fish had stomachs literally crammed with emerald shiners. In Green Bay, Lake Michigan, Van Oosten and Deason (1938) noted that emerald shiners made up about 64% of the food of lake trout, especially in spring. In a study of the smallmouth bass in Lake Erie, Doan (1940) listed the emerald shiner as the chief food fish. The importance of the emerald shiner to the Lake Erie fishery before 1970 has been well documented, and the story is similar in other lakes where studies have been conducted. In Lake Simcoe, McCrimmon (1956) noted that the emerald shiner was the most common minnow and served as an important food item of most sport fishes at some season of the year. Emerald shiners are eaten extensively by burbot, rainbow trout, and northern pike and to a lesser extent by other species. MacKay (1963) reported 87 individuals in the stomach of a single Atlantic salmon from Trout Lake, Ont.

Many fish-eating birds, such as gulls, terns, mergansers, and cormorants feed heavily upon emerald shiners, whose surface swimming habits makes them particularly susceptible to this kind of predator.

Man, of course, is an exceedingly influential predator taking many thousands of fish for use as bait.

The identification of ingested small fishes in general, and minnows in particular, is usually very difficult. Undoubtedly, emerald shiners are eaten much more extensively in other Canadian lakes than our meagre evidence indicates.

Bangham (1955) examined for parasites five fish from Providence Bay and South Bay, Manitoulin Island, Ont., and found all five lightly infected. Bangham and Hunter (1939) listed trematodes, cestodes, nematodes, and the protozoan Myxosporidia from lake shiners in Lake Erie. Hoffman (1967) noted that trematodes and cestodes have been recovered, but the number of species was comparatively small.

Relation to man The emerald shiner is probably used more often as bait, largely because of availability, than any other single species. It is also pickled and bottled and sold as preserved or pickled minnows for bait. The most intensive use is in connection with the Lake Simcoe winter ice fishery for whitefish and the spring fishery for yellow perch. The role of the emerald shiner in the Lake Simcoe fishery, particularly its use fresh, frozen and salted, as bait for lake whitefish, has been thoroughly discussed by McCrimmon (1956).

Nomenclature

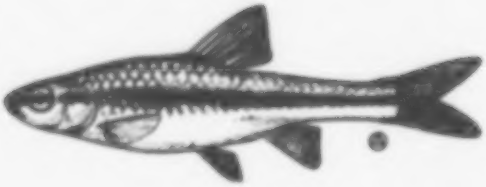
Notropis atherinoides	— Rafinesque 1818a: 204 (type locality Lake Erie)
Alburnus rubellus	— Agassiz 1850: 364
Alburnus nitidus	— Kirtland 1854a: 44
Alburnellus jaculus	— Cope 1869: 387
Notropis atherinoides (Rafinesque)	— Evermann and Goldsborough 1907a: 97
Leuciscus copii Günther	— Jordan, Evermann, and Clark 1930: 123

Etymology *Notropis* — back; keel; *atherinoides* — from *atherina*, the silverside; resemblance.

Common names Emerald shiner, lake shiner, lake emerald shiner, common emerald shiner, shiner. French common name: *méné émeraude*.

BRIDLE SHINER

Notropis bifrenatus (Cope)



Description Body slender, small, seldom exceeds 2 inches (51 mm) total length, somewhat compressed laterally, body slightly deeper than wide, its depth 15–22% of total length. Head length 20–23% of total length; eye relatively large, its diameter 31.2–38.8% of head length; snout length usually smaller than eye diameter, 26.6–33.3% of head length; interorbital width 33.3–44.4% of head length; mouth small, terminal, angle rather oblique, upper jaw extending backward almost to anterior margin of eye; pharyngeal teeth short, slightly hooked, 0,4–4,0. Fins: dorsal 1, rays usually 8(23) or 7(12), caudal forked; anal 1, rays usually 7(19), occasionally 8(6); pelvics thoracic, originating directly beneath origin of dorsal fin, rays 8(16), occasionally 7(4); pectorals moderate, the rays usually 12(13), but occasionally 11(2) or 13(5). Scales, cycloid, large, 32–35 in lateral series; lateral line incomplete. Peritoneum silvery and lightly speckled. Vertebrae 34–36.

Nuptial tubercles not conspicuous, but fine tubercles develop on males on pectoral fins and sometimes on head and nape.

Colour A straw-coloured minnow, silvery above and silvery white on the underparts, all fins transparent; spawning males always bright yellow-gold below the black lateral band, females without yellow colouring but are white below; rays of dorsal, caudal, and anal fins take on a yellow tint on both males and females; anterior pectoral rays of males become a more intense brown than on females.

Distribution The bridle shiner occurs in the Atlantic drainage of eastern North America from southern Maine to Virginia, west through Lake Champlain to New York State and the Lake Ontario basin.

In Canada its range extends from the upper St. Lawrence River, in the vicinity of Trois-Rivières, west through the St. Lawrence system including lakes Saint-Pierre and Saint-Louis (Cuerrier et al. 1946), to Lake Ontario where it extends only to the Bay of Quinte.

Radforth (1944) considered that the species survived glaciation in the Atlantic coastal plain and entered Canada in relatively recent times and thus it might well be in the process of expanding its range here. Unfortunately, the region in which it occurs is either heavily industrialized, heavily populated, or both, creating sewage disposal problems that will probably prevent the manifestation of such potential.

Biology Many studies of the life story and structure of the bridle shiner have been made by R. W. Harrington (1947a, 1948a, b, 1955), who worked with New England populations. We could find no evidence that Canadian populations have been studied.

Spawning may extend from late May to mid-July in New Hampshire, and from early May to August in New York State. In New

Hampshire, spawning groups were observed by Harrington (1948a) to consist of few females (3) and many males (29). The eggs were of the order of 0.03 inches (0.8 mm) in diameter; they appeared to mature progressively in accord with the prolonged spawning period. Mansueti and Hardy (1967) illustrated and described larval stages in the Chesapeake Bay region.

Food of the bridle shiner in New Hampshire has been thoroughly investigated by Harrington (1948a). It is primarily a predaceous species eating small planktonic animals of various kinds, whereas plant materials make up only a small part of the diet. Among the animals consumed were aquatic insect larvae, especially chironomids and entomostracans, notably cladocerans and copepods.

Bridle shiners are characteristic of clear quiet streams or lagoons that have an abundance of submerged aquatic vegetation, and where the bottom is composed of silt, or silt and sand. In such situations they may be very numerous.

Their small size and relatively weak swimming ability make them an ideal forage fish. In the eastern United States they are regarded as one of the principal foods of the pickerel, *Esox niger*. In Canadian waters they undoubtedly perform a similar role, although we have no supporting evidence. It seems safe to presume, however, that they form, or did form, an important food item in the diet of black crappies, smallmouth bass, yellow perch, and white perch in eastern Lake Ontario waters. It would be interesting to know if the explosive numbers of white perch in eastern Lake Ontario have seriously affected bridle shiner populations.

Hoffman (1967) listed the larval form of only one parasite, the trematode *Centrovarium lobotes*, from the bridle shiner. There are no Canadian records of infestation of this species.

Relation to man Like all forage fishes, the bridle shiner is an important food item for other fishes whenever it occurs in sufficient numbers to be a significant food source. It can be used as a bait minnow for anglers, but its small size and delicate structure limit its usefulness for this purpose.

Nomenclature

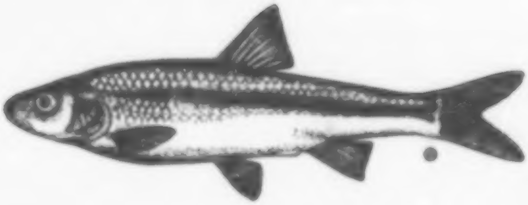
Hybopsis bifrenatus — Cope 1869: 382, 384 (type locality tributary Schuylkill River, Conshohocken, Pa.)
Notropis kendalli — Evermann and Cockerell 1909: 186
Notropis bifrenatus (Cope) — Jordan and Evermann 1896–1900: 258

Etymology *Notropis* — back; keel; *bifrenatus* — *bis* — two; *frenatus* — bridled.

Common names Bridle shiner, bridled shiner. French common name: *méné d'herbe*.

RIVER SHINER

Notropis blennius (Girard)



Description Body stout, average length 2.5–3.0 inches (64–76 mm), moderately compressed laterally, its greatest depth 15.9–19.4% of total length. Head bluntly triangular, large, its length 19.4–22.6% of total length; eye relatively large, its diameter 25.8–33.3% of head length; snout rounded and slightly overhanging the mouth, snout length 26.0–35.7% of head length; interorbital wide, its width 30.4–42.8% of head length; mouth large, subterminal, premaxillary terminating below anterior margin of eye; pharyngeal teeth stout, with slight hook, 2,4–4,2; but may be 2,4–4,1; 1,4–4,1; 3,4–4,1. Fins: all transparent; dorsal 1, its origin more or less directly over pelvic fin origin, rays almost always 8(30), rarely 7(1); caudal distinctly forked; anal 1, originating at a point below tip of depressed dorsal, rays 7(31); pelvics small, originating about directly below dorsal fin origin, pelvic axillary process present but very inconspicuous, rays 8(25); pectorals moderate in size, rays usually 14(16), sometimes 13(8) or 15(6). Scales cycloid, large, 38–45 in lateral line; lateral line complete, only slightly decurved, almost straight. Peritoneum silvery; intestine short. Vertebrae 36(18) or 37(3).

Nuptial tubercles on breeding males on snout, top of head, on rays of pectoral fins, and on leading edges of dorsal and anal fins.

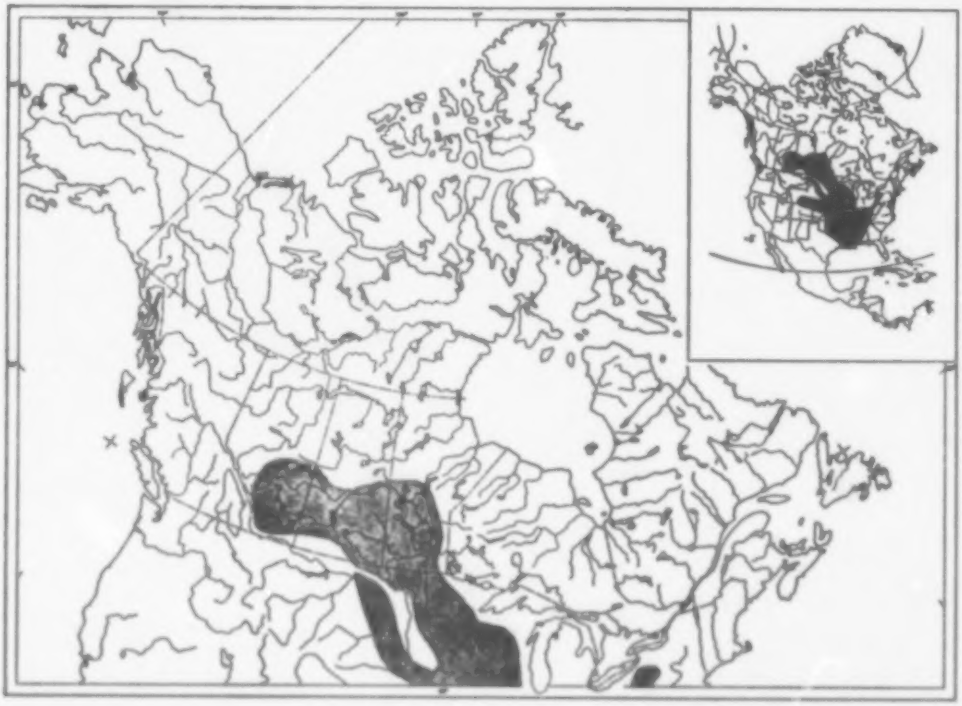
Colour General overall colouration is silvery but light brown to straw-coloured dorsally. Mid-dorsal stripe well developed, surrounding base of dorsal fin. Midlateral stripe indistinct, lateral line pores not outlined. Spawning adults not brightly coloured.

Systematic notes Hubbs and Lagler (1964) referred the northwestern North American populations, including the Canadian populations, to the subspecies *N. b. jejunus*. In the absence of definite studies, it seems advisable only to state the characteristics of the Canadian populations. A discussion of the zoogeography of the species and morphometrics of some United States populations were presented by Metcalf (1966).

Distribution A central North American minnow, occurring from eastern Texas and Alabama north to southern Ohio on the east and the Prairie Provinces on the northwest.

In Canada the river shiner occurs from the Red River system of southern Manitoba, westward, especially in the South and North Saskatchewan River systems, through Saskatchewan to southeastern Alberta.

Biology Few detailed studies have been made of the river shiner in either the United States or Canada. Consequently, we have little knowledge of its biology. Trautman (1957) discussed the species in Ohio and remarked that it spawned throughout the summer until late August, over a sand and gravel bottom.



Hoffman (1967) listed three species of Protozoa as parasites of the river shiner. There are no Canadian records of infestation of the species.

Relation to man So far as we are aware, the role of the river shiner in the biological economy of Canadian fresh waters is unknown.

Nomenclature

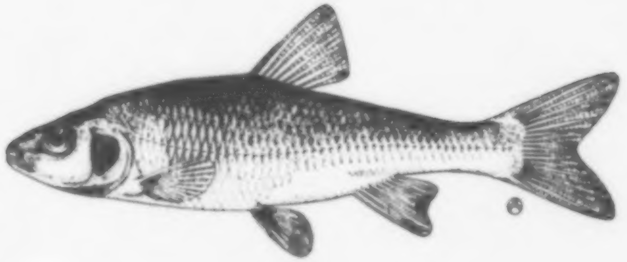
Alburnops blennius — Girard 1857a: 194 (type locality Arkansas River)
Episema jejuna — Forbes 1878: 60
Notropis reticulatus — Eigenmann and Eigenmann 1893a: 152
Notropis blennius (Girard) — Jordan and Evermann 1896–1900: 261
Hybognathus stramineus Cope — Jordan and Evermann 1896–1900: 262
Notropis deliciosus (Girard) (as used by Eigenmann 1895: 110) — Evermann and Goldsborough 1907a: 96
Notropis jejunus Forbes — Halkett 1913: 64
Hybopsis blennius (Girard) — Jordan, Evermann, and Clark 1930: 133
Paranotropis jejunus (Forbes) — Jordan, Evermann, and Clark 1930: 125

Etymology *Notropis* — back; keel; *blennius* — from *blennos*, the blenny which has mucus on its scales.

Common names River shiner, poor minnow, straw-coloured minnow. French common name: *méné de rivière*.

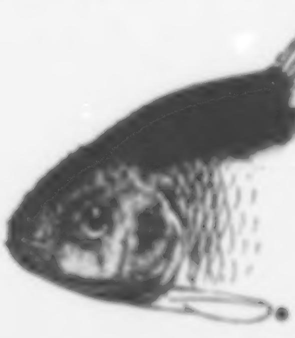
COMMON SHINER

Notropis cornutus (Mitchill)



Description Body stout, average length 2.5–4.0 inches (64–102 mm), distinctly compressed laterally, greatest depth 15.8–23.4% of total length; head triangular, its length 18.8–23.3% of total length; eye relatively large, its diameter 23.0–35.7% of head length; snout pointed, its length 28.5–35.2% of head length; interorbital wide, its width 33.3–46.1% of head length; mouth large, terminal, premaxillary terminating below anterior margin of eye; pharyngeal teeth, hooked, 2,4–4,2; 2,4–4,0; 1,4–4,1. Fins: dorsal 1, its origin over pelvic fin origin, rays always 8(65); caudal distinctly forked; anal 1, originating below tip of depressed dorsal fin, rays usually 9(54), sometimes 8(19), rarely 10(1), the latter in New Brunswick; pelvics small, originating under dorsal fin origin, rays usually 8(47), rarely 9(3); pectorals relatively small, rays usually 16(25), sometimes 15(11) or 17(14). Scales cycloid, those along flanks elevated, higher than wide, 40–44 in lateral line; lateral line decurved, complete. Peritoneum black; intestine short. Vertebrae 38–43, usually 39 or 40.

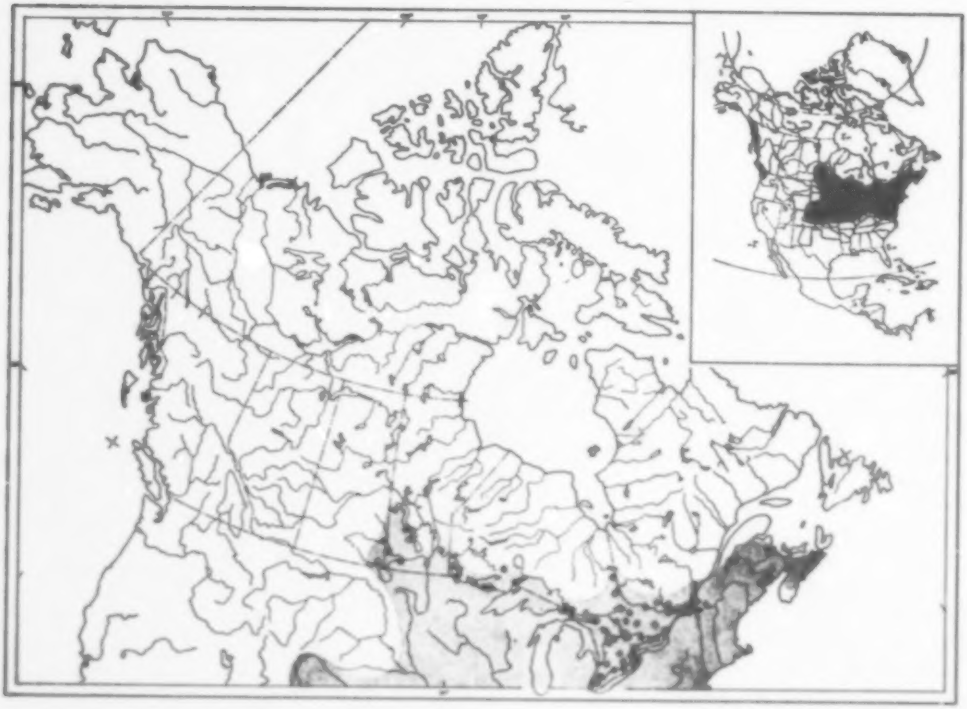
Nuptial tubercles on breeding males dense on snout, less dense on top of head, extending on nape to leading edge of dorsal fin, a single row on each side of mandible.



Colour Overall colouration silvery with bronze tints, but back is olive-green with a purple or gray-blue dorsal stripe, silvery on sides and silvery white below. Small specimens, under 2.5 inches (64 mm), usually silvery without bronze tint and with clear fins; mature males often with darkened dorsal fin.

Breeding males are brightly coloured, with pink or red on the outer third of all fins and a pink tint to anterior flanks and head. In addition to the mid-dorsal stripe, another golden stripe, particularly bright on spawning males, extends along the length of the body on each side, a few scale rows down from the centre stripe. *See* colour illustration facing p. 442.

Systematic notes A most thorough review of *N. cornutus* and closely related species was published by Gilbert (1964), which included meristic values for the species throughout its range. In the figures given



below, the vertebral number was calculated differently from ours. Gilbert included the urostylar vertebrae whereas we did not, and so Gilbert's values were adjusted accordingly. The frequency of occurrence of vertebrae number and anal fin ray count for *Notropis cornutus* throughout its range (from Gilbert) compared with values from various Canadian localities are as follows:

Vertebrae	Gilbert	Canada
35	2	–
36	–	–
37	2	–
38	36	2
39	136	10
40	55	14
41	6	3
Anal rays		
8	100	19
9	749	54
10	20	1

Gilbert included southern Ontario, in particular the Thames River, in the range of *Notropis chrysocephalus*. However, although the Thames populations exhibit the characters of *chrysocephalus*, the distinctions are not clear cut and we decided not to attempt to write an account for *chrysocephalus*. If Gilbert is correct in his assessment of *chrysocephalus*, i.e., that it tolerates warmer, more turbid waters than *cornutus* and is replacing it in areas where such conditions exist, then *chrysocephalus* should extend its range in Ontario and replace *cornutus* in many southern Ontario streams.

Distribution The common shiner is widely distributed in clear lakes and streams from Nova Scotia on the Atlantic coast south to the James River system in Virginia, west through the southern Great Lakes drainage region to Saskatchewan, and south throughout most of the Mississippi valley. Metcalf (1966) noted that its range, particularly in the Kansas River basin where it was once widely distributed, has been reduced because of turbidity resulting from agricultural practices in that area, and other similarly utilized regions in Iowa.

In Canada the common shiner has been reported to occur in Nova Scotia from Goshen Lake, Guysborough County, to Pockwock Lake, Halifax County, and northwest to Gilbert Lake, Cumberland County; in New Brunswick widely distributed throughout the province; in southern Quebec; in Ontario in southern parts of the Great Lakes–St. Lawrence River drainage occurring north to Lake Temiskaming and west to Lake of the Woods. Radforth (1944) noted that its Ontario distribution appeared to be related to the 65° F July isotherm. In Manitoba it is recorded from Whitemouth and Cypress rivers, and some of the western tributaries of Lake Dauphin, Swan Lake, and the Red River (Keleher and Kooyman 1957). Atton and Johnson (1955) reported a single large specimen from Whitesand River at Canora on June 16, 1954, and a number of smaller specimens from the Souris River at Oxbow on July 27, 1954. These specimens from Saskatchewan represent the western extent of the range.

It is absent from Newfoundland, Prince Edward Island, Alberta, British Columbia, the Northwest Territories, and the Yukon Territory. Gilbert (1964: 148) noted a specimen in the United States National Museum collection (USNM 86211) bearing the locality data of Medicine Hat, Alta. Since the collection also contained specimens of other eastern cyprinids, such as *Semotilus corporalis* and *Pimephales notatus*, the author concluded that the locality data had been transposed.

Biology The reproductive phase of the life history of the common or creek shiner has been fully described by Raney (1940a) and most recent accounts refer to this classical work. Raney's own observations were made near Ithaca, N.Y. Published observations of spawning or other activities of this species in Canadian waters are exceedingly rare.

This is, perhaps, exclusively a stream-spawning species, but it is sometimes so abundant in lakes as to suggest that it may spawn on gravelly shoals. In spring, usually in May, lake populations move inshore in preparation for spawning.

The actual date of spawning is apparently related to water temperature but there seems to be wide variation of temperature at which spawning begins, throughout its United States range at least. Raney reviewed the temperature data presented by various authors, and it seems likely that spawning usually begins when water temperatures reach 60°–65° F (15.6°–18.3° C), usually in May or June. As noted earlier, its northern distribution in Ontario seems to bear a relation to the 65° F (18.3° C) isotherm, which corresponds with the required 60°–65° F temperature for spawning. Greeley (1929) observed spawning in the Lake Erie drainage of New York State at a temperature of 83° F (28.3° C) as late as July 9.

Spawning may occur over gravel beds in flowing water; the fish may excavate shallow nests in gravel in flowing water, or they may use the nests made by other fishes, even though such nests lack a current flow. They often spawn at the head of a gravelly riffle, a site probably used frequently in our waters. In such situations, the male establishes a territory, usually consisting of a few square inches, may effect some cleaning of the gravel by dislodging stones with his head, and is frequently involved in fights with other males in defense of his territory. The usefulness of the nuptial tubercles is apparent during these activities. The females stay on the gravel below the males until ready to spawn, then they move upstream and eventually the spawning act is completed. The male encloses the female within the curve of his body, and exerting pressure on the body of the female, he forces the extrusion of the eggs. This spawning act takes place in a fraction of a second and is repeated many times, often within a few minutes, and there may be a constant succession of males and females moving onto the spawning site, spawning, and dropping back. Raney suggested that few eggs, probably not more than 50, were released at each spawning. The habit of spawning over the nests of other minnows, or in riffles upstream from spawning sites of other minnows, and the subsequent mixing of sex products, results in the production of many natural hybrid forms of which *N. cornutus* is one parent. Hybrid combinations with *N. rubellus*, *Semotilus atromaculatus*, and *S. corporalis* have been reported, some as new species (*see* Hubbs and Brown 1929: 37).

The eggs, each about 1.5 mm in diameter, are demersal, become adhesive after about 2 minutes of water hardening, and lodge among the gravel. Fish (1932) described the development and figured the egg and three larval stages to a length of 13.2 mm. Few studies on rates of growth have been published. This is the largest member of the genus *Notropis*; males may grow to lengths of 6.9–7.9 inches (175–201 mm) total length. The largest specimen known to us is one from Lake Bernard, Que., 7.9 inches (201 mm), but one from the Whitesand River, Sask., near the western limit of the Canadian range, measured 7.5 inches (190 mm). These large fish were all males.

Although principally a stream fish through most of its range, the common shiner frequently occurs in the shore waters of clear-water lakes, particularly in the central portion of its Canadian range.

The food of common shiners has received much attention. Aquatic insects, adults and larvae, may figure prominently in the diet and so also may algae and other aquatic plants. Protozoans, desmids, and small fishes have also been reported. Although it usually feeds at the surface, it will also take food off the bottom. Gilbert (1964) suggested that its versatility in feeding habits probably partly accounts for its considerable success as a species.

The common shiner is preyed upon by a variety of other creatures, but because streams are its preferred habitat it avoids predation by many game species except in the lower reaches where deeper water affords protection to smallmouth bass, northern pike, and other large fish. White (1957) discovered that the common shiner could constitute up to 40% of the diet of American mergansers in streams in New Brunswick and other parts of the Maritime Provinces. Kingfishers are also predators on shiners.

Parasites of the common shiner have been reported by Bangham and Hunter (1939) for Lake Erie and Bangham (1955) for Lake Huron, but the degree of parasitism appeared to be comparatively light. *See* Bangham (1955) for details. Local populations sometimes exhibit *Ligula intestinalis* infections and such a case was reported by Dence (1958) for the Adirondack region of New York.

Hoffman (1967) gave a lengthy list of parasites found in this species, including protozoans, trematodes, cestodes, nematodes, acanthocephalans, molluscs, and crustaceans.

Relation to man The common or creek shiner is a very commonly used bait species. Its large size and silvery appearance make it particularly attractive for northern pike and walleye fishing, although shiners caught in cool, clear streams do not live for long in the confines of a neglected minnow pail.

Because of its need of gravelly riffles for spawning, it is not usually regarded as well suited to pond culture; also Dobie et al. (1956) noted that attempts to strip eggs from females had been unsuccessful.

Nomenclature

Cyprinus cornutus — Mitchill 1817: 289 (type locality Wallkill River, N.Y.)
Cyprinus megalops — Rafinesque 1817b: 121
Leuciscus cornutus — DeKay 1842: 207
Leuciscus vittatus — DeKay 1842: 212
Leuciscus frontalis — Agassiz 1850: 368
Leuciscus gracilis — Agassiz 1850: 370
Minnilus cornutus Mitch. — Cox 1893: 40
Notropis megalops — Eigenmann 1895: 110

Minnilus cornutus (Mitchill) — Cox 1896b: 64
Luxilus cornutus (Mitchill) — Jordan, Evermann, and Clark 1930: 128
Notropis cornutus — Gilbert 1964: 140

Etymology *Notropis* — back; keel; *cornutus* — horned.

Common names Common shiner, eastern shiner, redfin shiner, silver shiner, dace, silverside, rough-head, hornyhead, creek shiner. French common name: *méné à nageoires rouges*.

BIGMOUTH SHINER

Notropis dorsalis (Agassiz)

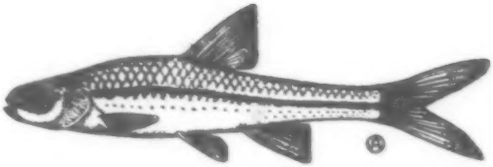
Description Body conpressed laterally, length to about 2.5 inches (64 mm), its greatest depth 16.6–20.2% of total length. Head bluntly triangular, large, its length 20.6–25.0% of total length; eye relatively large, its diameter 24.6–30.0% of head length; snout moderate, its length 25.0–31.5% of head length; interorbital moderate, width 29.4–38.0% of head length; mouth large, extending to below anterior margin of pupil of eye; pharyngeal teeth mainly 1,4–4,1 but some variability to 0,4–4,1 or 1,4–4,0, teeth with slight hook. Fin: dorsal 1, its origin over or slightly behind origin of pelvic fin, rays 8(10); caudal forked, lobes pointed; anal origin below free margin of depressed dorsal fin, rays 8(10); pelvics originate under or slightly in advance of dorsal fin origin, rays 8(10); pectorals well developed, rays 14(7) or 15(3). Scales cycloid, deciduous; lateral line complete; peritoneum silvery. Vertebrae 34(3), 35(7), 36(4), or 37(1).

Mr A. N. Fedoruk, Canada Land Inventory project, reported capture of 53 specimens of *Notropis dorsalis* (Agassiz) in June 1969 in the Pembina River, Man. (township 6 Range 1 W), 5 miles upriver from the point where the Pembina crosses into North Dakota. This is the first record for this species in Canada. The above description is based on a study of 10 of these specimens. A second occurrence in southern Manitoba has also been noted, in the Woody River.

The characteristic features to look for are: large mouth, a distinct lateral band, especially on posterior part of trunk and caudal peduncle and a distinct mid-dorsal stripe. It closely resembles *Notropis blennius*.

PUGNOSE MINNOW

Notropis emiliae (Hay)



Description Body slender, elongate, averaging 2 inches (50 mm) total length, robust anteriorly, not strongly compressed laterally, its depth 15.3–21.1% of total length. Head bluntly rounded, small, its length 17.3–20.0% of total length; eye moderate, its diameter 30.0–33.3% of head length; snout rounded, its length somewhat greater than eye diameter, 30–35% of head length; interorbital broad, its width 36.8–44.4% of head length; mouth very small and at an acute angle; pharyngeal teeth slender but serrated and hooked, 0,5–5,0. Fins: dorsal 1, inserted over or slightly behind origin of pelvic fins, rays 9; caudal distinctly forked; anal 1, its origin behind insertion of dorsal fin, rays 8; pelvics originate below or slightly in advance of dorsal fin origin, 8 rays; pectorals short, about 15 rays. Scales cycloid, 37–41 in lateral line; lateral line complete, slightly decurved. Peritoneum silvery, but heavily speckled with chromatophores. Vertebrae 37 or 38.

Nuptial tubercles on breeding males restricted to many small, sharp tubercles around the mouth.

Colour Overall colouration silvery, but with straw-colour or light olive overtones and often appearing somewhat translucent; a distinct midlateral band, becoming less distinct anteriorly on head, through eye and around snout. Slight concentration of melanophores at base of central caudal rays. Scales on back and sides distinctly outlined with pigment.

Distribution A North American minnow restricted primarily to the Gulf states and Mississippi valley, the pugnose ranges from Florida to Texas, north in the Mississippi valley and tributaries, to western Lake Erie, west to southern Wisconsin and southern Minnesota.

In Canada the pugnose is a rare minnow and has been reported from the Detroit River, and from Lake St. Clair and its tributary, the Thames River. Captures on the Canadian side of the Detroit River have not been made since 1941, but 7 specimens were caught in the Thames River in October 1968 and reported to the authors.

Biology Information on the biology of this small minnow is almost as rare as is the species itself in Canadian waters, and we have no information on its reproductive biology.

The pugnose minnow apparently prefers clear, slow-moving waters having an abundance of aquatic vegetation, precisely the type of habitat that is rapidly disappearing from southern Ontario. Trautman (1957) noted that the species was intolerant of turbid or muddy waters (conditions unsuited to successful growth of aquatic plants) and was threatened with extirpation from Ohio waters. It seems most unlikely that the species will be able to survive for long in Ontario waters.

Bangham and Hunter (1939) examined 10 specimens from Lake Erie and found 2 infected with the trematodes *Neascus* sp., and *Lebouria cooperi*, and the larval or immature form of the cestode *Ligula intestinalis*.

Relation to man The pugnose minnow is too rare and restricted in distribution to be of any real importance in Canada.

Nomenclature

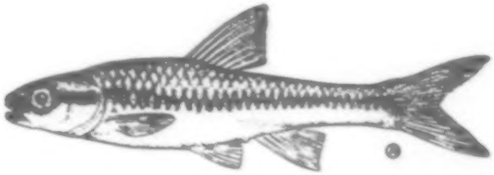
Opsopoeodus emiliae	— Hay 1881: 507 type locality Artesia, Macon, and Enterprise, Miss.)
Notropis emiliae (Hay)	— Bailey et al. 1970: 22

Etymology *Notropis* —back; keel; *emiliae* — named for Mrs Emily Hay.

Common names Pugnose minnow. French common name: *petit-bec*.

BLACKCHIN SHINER

Notropis heterodon (Cope)

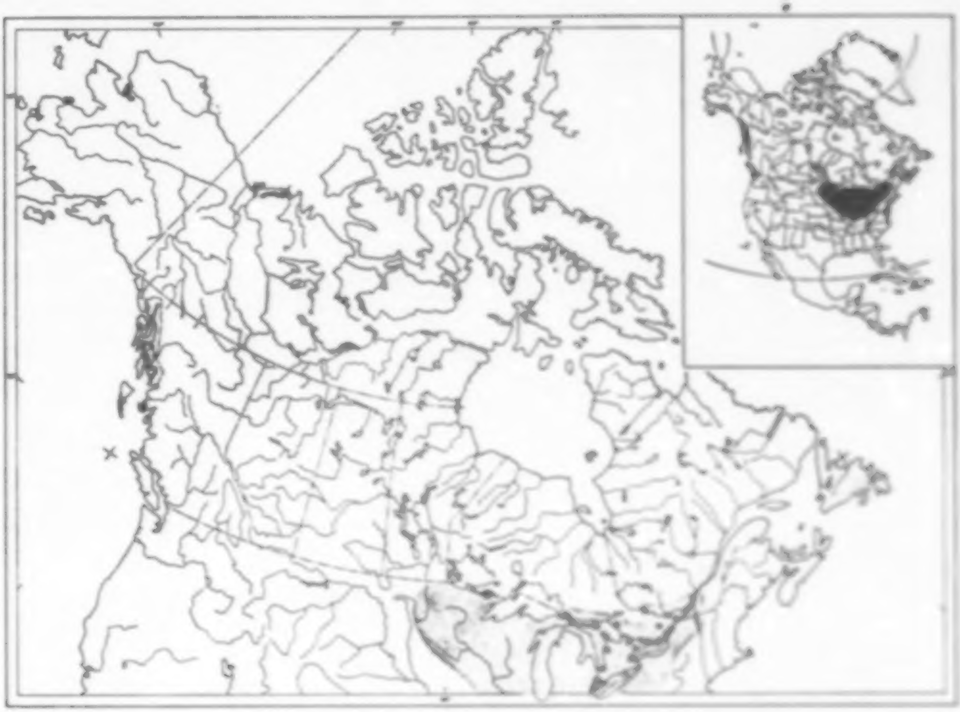


Description A stout-bodied little fish, average length about 2.5 inches (64 mm), only slightly deeper than wide, its greatest depth 15.0–24.5% of total length. Head bluntly triangular, its length 20.0–23.8% of total length; eye relatively large, its diameter 25–40% of head length; snout short, its length 23.8–34.7% of head length; interorbital wide, its width 27.2–40.0% of head length; mouth small, terminal, premaxillary terminating below nostrils; pharyngeal teeth with broad base, pointed, 1,4–4,0; 1,4–4,1; 1,3–4,1. Fins: more or less trans-transparent; dorsal 1, its origin more or less directly over pelvic origin, rays usually 8(46), occasionally 7(3); caudal distinctly forked; anal 1, rays usually 7(31), often 8(17); pelvics originate below dorsal fin origin, rays usually 8(37), rarely 7(1); pectorals short, rays usually 13(14) or 14(14), often 12(10). Scales cycloid, clearly outlined with black above lateral band, 34–37 in lateral line; lateral line slightly decurved, incomplete. Peritoneum silvery. Vertebrae 35 or 36.

Nuptial tubercles on breeding males, very fine, on top of head and upper surface of pectoral fins.

Colour Typically silvery but straw-coloured or yellowish dorsally and white ventrally. The scales on the back are edged with dark pigment. Lateral band dark and distinctive on the body, forming a zigzag pattern, extending onto the head, through the eye, and around the snout and also onto the chin, chin black. Spawning fish are said not to develop bright colours, but field observations in Point Pelee, Ont., area suggested pale yellowish tinge on ventral surface.

Systematic notes *See* section on *Systematic notes* for *Notropis anogenus*, which this species resembles so closely.



Distribution The blackchin shiner occurs only in the Great Lakes basin and tributary watersheds of the north-central portion of North America.

In Canada it ranges from the upper St. Lawrence River (Trois-Rivières), western Quebec, the Ottawa River drainage in the vicinity of Pembroke, west through Lakes Ontario, Erie, St. Clair, and Huron and their tributary streams, north to Sault Ste. Marie (and has been reported from at least six Michigan streams tributary to eastern Lake Superior); recently recorded from Quetico region, Ont.

Clear, clean, weedy waters are essential for survival of the blackchin shiner and it is especially noteworthy that it has been eliminated from the Iowa fauna during the last 25 years and from Ohio waters since around 1950, presumably because of the drastic changes in water quality and loss of habitat.

Biology The life history and ecology of the blackchin have received little attention and definitive studies have not been made or, at least, not published. Certainly there is practically no biological information on Canadian populations.

It has been reported to spawn in May and June in central Illinois. Spawning site and behaviour have not been reported.

Trautman (1957) reported the following growth figures (length) for Ohio specimens: young-of-the-year (October) 0.7–1.4 inches (18–36 mm), around 1 year 1–2 inches (25–51 mm). Adults from Canadian waters average 2.0–2.4 inches (51–61 mm).

The blackchin shiner requires clear weeded waters for survival and seems to prefer quiet pools in creeks and rivers and weedy inshore waters of lakes.

Its food has been reported to consist principally of small crustaceans, such as cladocerans, copepods, and other entomostracans, and small insects. Keast (1965) in a study based on Lake Opinicon, Ont., considered it a specialized feeder, the overwhelming bulk of food ingested from May to August being

Cladocera and flying insects (mainly small Diptera) taken at the surface. Among Cladocera, *Chydorus* and *Bosmina* were the main genera consumed, 400–700 occurring per 10 stomachs in June and July, and some larger *Daphnia* consumed in August.

Bangham (1955) examined one specimen only from South Bay, Manitoulin Island in Lake Huron, and reported one each of two larval trematodes, *Diplostomulum* sp. and *Posthodiplostomum minimum*, from this fish. Bangham and Hunter (1939) recorded the trematode *Neascus* sp. and nematodes *Agamonema* sp. and *Camallanus oxycephalus* in three of the eight specimens examined from the western end of Lake Erie.

Hoffman (1967) listed three species of trematodes, and three species of nematodes, from the blackchin shiner in North America.

Relation to man The blackchin shiner may be an important forage fish whenever it occurs in sufficient numbers but we have no direct evidence. It is probable that it is at least of minor importance in the diet of black crappies in the Rideau lakes region of eastern Ontario since it has been reported by Toner (1943) from a number of lakes in the area.

It is occasionally sold as a bait minnow mixed with other species of *Notropis* (shiners), but is not recognized as a distinct species by bait dealers or fishermen.

Nomenclature

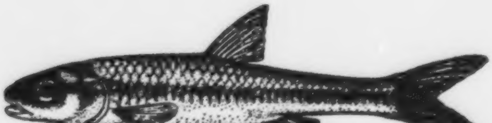
Alburnops heterodon	— Cope 1864: 281 (type locality Grosse Isle, Mich.)
Hybopsis heterodon (Cope)	— Jordan, Evermann, and Clark 1930: 136
Notropis heterodon	— Scott 1967: 67

Etymology *Notropis* — back; keel; *heterodon* — varying; tooth.

Common names Blackchin shiner. French common name: *menton noir*.

BLACKNOSE SHINER

Notropis heterolepis Eigenmann and Eigenmann



Description A stout-bodied little fish, inclined to have a prominent bulging abdomen, average length about 2.5 inches (64 mm), deeper than wide, greatest body depth 13.3–21.3% of total length; head bluntly triangular, its length 19.6–22.9% of total length; eye large, its diameter 25.0–37.5% of head length; snout slightly rounded and projecting slightly beyond lower jaw, its length 25.0–36.3% of head length; interorbital wide, its width 30.0–42.1% of head length; mouth small, subterminal, premaxillary terminating below nostrils; pharyngeal teeth with slight hook, 0,4–4,0. Fins: transparent; dorsal 1, its origin more or less directly over pelvic origin, rays usually 8(69), occasionally 7(9), rarely 9(1); caudal distinctly forked; anal 1, rays usually 8(53), often 7(26); pelvics originate below dorsal fin origin, rays usually 8(62), rarely 7(2); pectorals short, rays usually 12(30), or 13(29), occasionally 14(4). Scales cycloid, clearly outlined with black above lateral band, 33–40 in lateral line; lateral line slightly decurved, complete. Peritoneum silvery. Vertebrae 34–36.

Nuptial tubercles on breeding males, very fine, on dorsal surface of head only.

Colour Overall colouration typically silvery but often with straw-coloured or pale yellow reflections, and silvery white below. Scales on the back outlined with black, making scale pattern obvious. A dark lateral band (sometimes inconspicuous on living specimens) extends midlaterally around the body and across the snout, but not onto the chin, this lateral band often not visible on body until after death. The anterior portion of the band, from operculum to at least below dorsal fin, characteristically made up of small, dark, crescent-shaped marks, whose convex surfaces are directed anteriorly. Northern populations are sometimes much darker than those from the lower Great Lakes.

Systematic notes The nomenclature for this species is rather confused in some of the early literature but Hubbs (1926) and Dymond (1926) provided explanatory data. The species was described by Eigenmann and Eigenmann (1893a), from a single specimen, 35 mm (1.4 inches) long, taken at "Fort Quappelle," Sask.

The species described by Bensley (1915) from Georgian Bay as "*Notropis cayuga*, var. *muskoka*, Meek" is *Notropis heterolepis*.

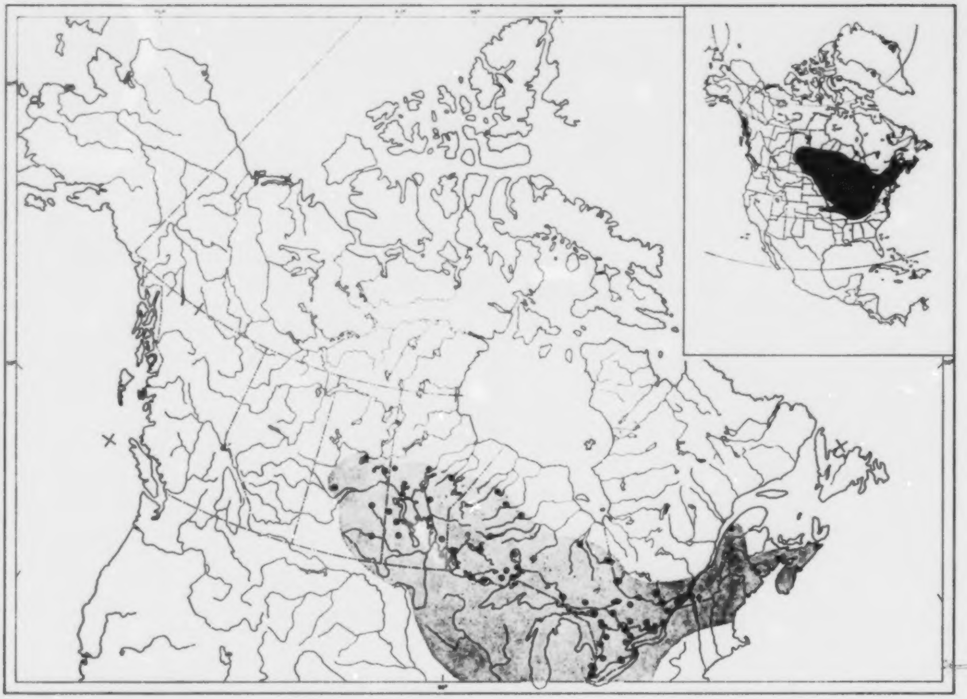
Hubbs and Lagler (1949) described as new a subspecies, *N. h. regalis*, from a small lake on the north side of Isle Royale, Lake Superior. The same authors would designate all Canadian populations as *Notropis heterolepis heterolepis*. But the degree of variability over the entire Canadian range is great and has not received careful study. It seems to us undesirable to make a subspecific designation for such widely separated populations without critical study.

The Cyprinidae regularly have branchiostegal ray counts of 3,3 but considerable variation was displayed by a sample of 10 specimens from Grand Lake, N.S., (ROM 11455), as follows: 3,3(2); 3,4(4); 4,3(3); 4,4(1). This population obviously warrants further study.

Distribution The blacknose shiner is widely distributed from the Hudson Bay drainage in Canada to the New England states west to Iowa. Bailey and Allum (1962) stated that, although the blacknose shiner was once a common minnow in South Dakota, it is now rare and they did not collect the species there. The reduction of clear, vegetated waters, which this minnow prefers, is cited as the cause of its disappearance in this region. Southward it occurs in Missouri and Tennessee, in the Mississippi valley in the Kansas River, but not in the Kansas River basin (Metcalfe 1966).

In Canada the species occurs in the east from Nova Scotia where Livingstone (1953) reported it common in the soft-rock areas of Windsor, Hants County, to Goshon Lake, Guysborough County. In New Brunswick it is found mainly in the waters of the southwestern area of the province, except for a collection from the Petitcodiac River reported by Scott and Crossman (1959). It is distributed through southwestern Quebec; through Ontario in weeded and sandy shallows of lakes, north to the James and Hudson Bay drainage of the north-central area; west in many lakes and streams in Manitoba, as far north as 55°N; in Saskatchewan reported from Waskesiu, Greenwater, Amisk, and other lakes (Rawson 1949).

It is absent from Newfoundland, Prince Edward Island, and from the area west of Saskatchewan. Not known from Northwest Territories, Yukon Territories, nor Alaska.



Biology Despite the fact that this is a wide-ranging species that at times occurs in considerable numbers, a detailed description of the biology of the blacknose shiner has apparently never been made. However, various authors have suggested that spawning occurs in spring and summer in parts of the northern United States, over sandy bottoms. Greeley (1929) reported finding females in spawning condition in the New York waters of the Niagara River on July 26, 1928. Dymond (1926) stated, simply, that spawning occurred in July in Lake Nipigon, Ont. Fish (1932) described and figured a young blacknose dace, 20 mm long.

Although details of growth rates are not available, maximum sizes of specimens in our collections range from 3.0 to 3.7 inches (75–95 mm) total length. One collection (ROM 3579) from a small lake in southern Ontario contains a number of specimens measuring 3.4–3.7 inches (85–95 mm) total length.

This small shiner prefers quiet clear, weedy bays and quiet streams, and, in our experience, primarily shallow water with sand or gravel bottom. However, Dymond (1939) found it most common in small lakes and streams with a muddy bottom in the Ottawa region.

Its food has not been reported in detail but it seems likely that Cladocera, insects, and green algae form a substantial part of its diet.

We have no direct evidence of predation but there can be little doubt that it forms a significant part of the diet of predaceous fishes that live in the same habitat. Through much of its Canadian range, especially in the central part, it may occur in numbers, at which times it would be a valuable forage species.

Bangham (1955) examined 25 specimens from South Bay and Lily Lake, Manitoulin Island, Ont., for parasites. The South Bay specimens carried only a single parasite, *Posthodiplostomum minimum*, but the Lily Lake specimens harboured additional species.

Bangham and Hunter (1939) found no parasites in the eight specimens they examined from the western end of Lake Erie.

Hoffman (1967) listed species of protozoans, trematodes, cestodes, one species of nematode, and one Mollusca from the blacknose shiner in North American waters.

Relation to man The blacknose shiner is frequently sold as bait in many parts of southern Ontario.

This small minnow is probably an important forage species in areas where it abounds, as it does (or did) in many parts of Ontario and western Quebec. However, its need for clear weedy waters and intolerance of turbidity will probably limit its distribution in many parts of its Canadian range. Trautman (1957) noted that it has been eliminated from many parts of Ohio where it was abundant before 1935, a trend that has been repeated in Iowa and other states.

Nomenclature

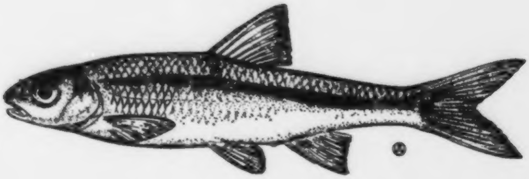
Notropis heterolepis — Eigenmann and Eigenmann 1893a: 152 (type locality Fort Qu'Appelle, Sask.)
Notropis albeolus — Eigenmann and Eigenmann 1893a: 152
Notropis jordanii — Eigenmann and Eigenmann 1893b: 592
Notropis muskoka — Meek 1899: 308
Notropis cayuga Meek — Jordan and Evermann 1896–1900: 260
Notropis cayuga, var. *muskoka*, Meek — Bensley 1915: 23
Hybopsis heterolepis (Eigenmann and Eigenmann) — Jordan, Evermann, and Clark 1930: 134

Etymology *Notropis* — back; keel; *heterolepis* — various; scale.

Common names Blacknose shiner, northern blacknose shiner, black-nosed minnow, blacknose dace, Muskoka minnow. French common name: *museau noir*.

SPOTTAIL SHINER

Notropis hudsonius (Clinton)



Description Body stout, usual length 2.5–3.0 inches (64–76 mm), compressed laterally, greatest depth 15.6–23.2% of total length. Head bluntly triangular, its length 17.4–21.4% of total length; eye relatively large, its diameter 25–40% of head length;

snout rounded and distinctly overhanging the mouth, snout length 25–35% of head length; interorbital wide, its width 33.3–43.7% of head length; mouth moderate, subterminal, premaxillary terminating below anterior margin of eye; pharyngeal teeth flattish, hooked, 2,4–4,2, but highly variable, to 0,4–4,0 and 0,3–3,1. Fins: dorsal 1, its origin directly over pelvic origin, rays almost always 8(62), rarely 9(1); caudal distinctly forked; anal 1, originating at a point in advance of tip of depressed dorsal, rays usually 8(59), rarely 7(4); pelvics small, originating directly below dorsal fin origin, pelvic axillary scale present but inconspicuous, rays 8(37), rarely 7(1); pectorals moderate in size, rays usually 14(16), 15(11), or 13(7), rarely 12(1), 16(1) or 17(2), high counts from southern Ontario. Scales cycloid, large, 38–42 in lateral line; lateral line complete. Peritoneum silvery; intestine short. Vertebrae 37–39, usually 38.

Nuptial tubercles on breeding males, very fine, on upper half of head and a few near the base of anterior pectoral rays.

Colour Overall colouration is silvery with yellow or golden overtones. The back is pale green to olive, the sides silvery, the belly silvery-white. The fins are mainly clear except for the black spot at the base of the caudal fin rays, which is most conspicuous on small fish about 2.5 inches (64 mm), but as they become larger the spot tends to become somewhat obscured by the silvery guanine and by the scales. Large fish of the order of 5 inches (127 mm), often show little evidence of the spot until after death and preservation. The spot is nearly always obvious after preservation even on large specimens.

Systematic notes Hubbs and Lagler (1964) considered *N. hudsonius* to be divisible into geographic races or subspecific groupings as follows: *N. h. saludanus* (Jordan and Brayton) of Virginia to Georgia; *N. h. amarus* (Girard) of the Delaware and Potomac River basins of the northeast; and *N. h. hudsonius* (Clinton) of the Mississippi valley and northward, but excluding the Great Lakes form, thought to be a distinct subspecies since these authors express doubt that the Great Lakes form is identical with the true *hudsonius* of the Hudson River, the type locality. Following an earlier decision of Hubbs and Lagler (1941), Dymond (1947) assigned populations in Lake Superior and northward to the subspecies *N. h. selene* (Jordan).

The limited data available to us (25 cleared and stained specimens) suggest that western populations may have a higher number of vertebrae. The data are admittedly meagre, but suggestive.

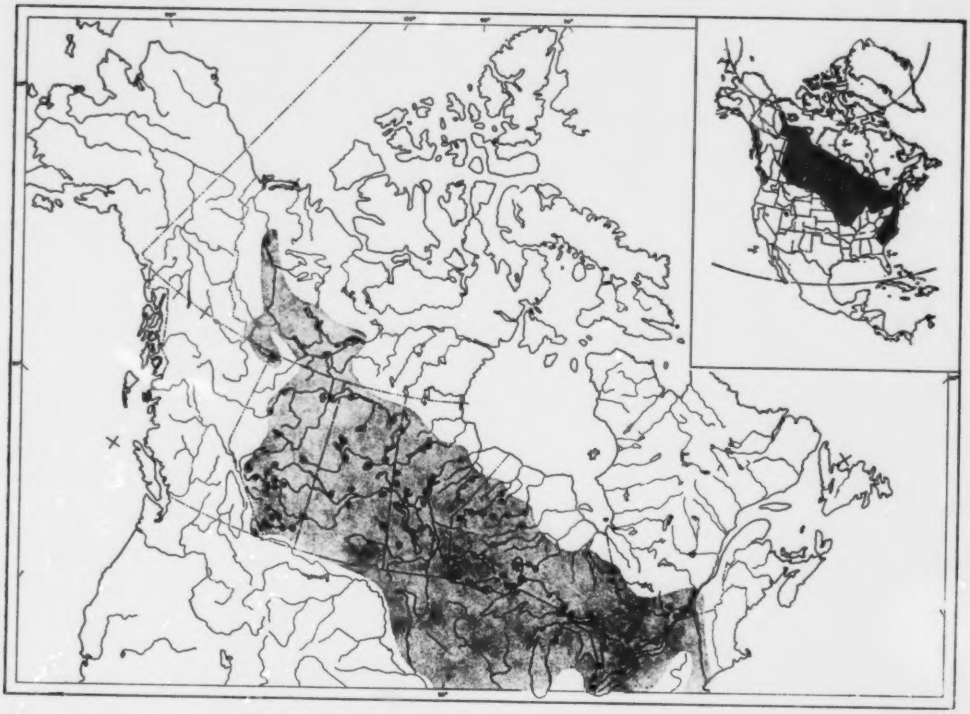
	Vertebrae no.			
	36	37	38	39
Que. (ROM 24002)	1	4	1	–
Ont. (ROM 16246)	–	2	9	–
Sask. (ROM 19056)	–	–	5	2
Total	1	6	15	2

Distribution The spottail shiner occurs in North America from portions of Canada south in the United States to Georgia in the east and Iowa and Missouri in the west. Not in Kansas (*see* Cross 1967).

In Canada the species is found in large bodies of water from about Trois-Rivières, in the St. Lawrence drainage of Quebec, west throughout the Great Lakes, north in Ontario to Big Trout Lake and to about 54°N. It is the most widely distributed species of *Notropis* in the Patricia Portion of Ontario. It is reported as common in Manitoba in almost all larger lakes and rivers (Hinks 1943). Wynne-Edwards (1952) reported its presence in the Saskatchewan–Nelson system and in Hayes River above York Factory. It is widespread and abundant in Saskatchewan, present in Alberta, and in many parts of the Mackenzie River system downstream to Good Hope, but has not been reported from the upper Liard nor upper Peace River systems (McPhail and Lindsey 1970).

It is absent from the waters of the Maritime Provinces, Newfoundland, British Columbia, and Alaska.

Biology The spottail shiner spawns in spring and early summer throughout its wide Canadian range, the precise date depending upon latitude and seasonal weather. Avail-



able evidence suggests that Canadian populations spawn over sandy shoals in June or July. For example, 58 specimens seined over a sand bottom in 3–4 feet of water in eastern Lake Erie, on June 16, 1949, were apparently spawning, for many eggs were found in the algae mass taken with the fish and the females readily extruded eggs with only slight pressure. However, Langlois (1954) reported ripe females taken in Lake Erie on May 15, and Fish (1932) stated spawning occurred in Lake Erie in late June and early July. Hence, it would seem that spawning in Lake Erie is prolonged or else the time of spawning varies greatly from year to year.

A report by Peer (1966) suggested that spawning must have taken place in 1960 in July in Nemeiben Lake, Sask., since all spottails seined before July 10 were in spawning condition and all seined after July 11 were spent. Spawning was considered to have taken place over sandy shoals in this case. Evidence that spottails use the mouths and lower reaches of tributary streams for spawning is scanty except for eastern Lake Superior. Here many hundreds of spottails were taken from June 11 to 20, 1954, at the mouths of such north shore streams as the Stokely, Harmony, and Sable, in gear installed for lamprey control. All fish were judged to be ripe and it was assumed that the aggregations were associated with spawning.

McCann (1959) reported egg sizes and number for Clear Lake, Iowa. Ripe females in May contained (mature, yellow-coloured) eggs as follows: yearlings, 70–90 mm total length, 100–1400 eggs; 2-year-old females, 1300–2600 eggs each. The eggs averaged 0.8 mm in diameter.

Data on rate of development and time to hatching appear to be lacking but Fish (1932) described larval stages and figured 5-mm and 14.25-mm stages, and Mansueti and Hardy (1967) illustrated and described larval stages in the Chesapeake Bay region.

The ages of spottail shiners can be determined by scale examination. Smith and

Kramer (1964), working with populations from Red Lake, Minn., demonstrated the validity of the scale method for age determination and presented data on rate of growth for large samples taken over a number of years. Females grew faster than males at all ages, but some years were shown to be better growing years than others. Calculated total lengths (mm) at time of annulus formation for various age-groups are as follows: age 1 (M = 56.4; F = 58.1); age 2 (M = 85.4; F = 90.1); age 3 (M = 100; F = 106.2); age 4 (M = 103.0; F = 113.1).

Maximum size (from ROM collections) is a specimen from Lake Erie that measures 5.2 inches (132 mm) total length. Spottails over 5 inches (127 mm) in length are unusual, except in Lake Erie.

The spottail is usually regarded as a fish of relatively large lakes and larger rivers and such may well be the case, but collections in the myriad of small Canadian lakes are quite inadequate. Seined collections are usually made in the daytime, whereas the spottail is usually more susceptible to capture by night seining, except in the northwesterly parts of its range. It is often the most abundant minnow in northern lakes. For example, G. H. Lawler (personal communication) provided the following figures of relative abundance for Heming Lake, Man., of cyprinids captured during fishing operations in 1961: 4407 *N. hudsonius*; 32 *N. heterolepis*; 1 *Pimephales promelas*.

We know little of the food of this important forage species in Canadian waters. Dymond (1926) noted that Lake Nipigon spottail shiners seemed to be more plankton feeding than emerald shiners, and that *Daphnia* formed 40% of the diet, although *Bosmina, Sida*, and *Leptodora* were also eaten. Aquatic insect larvae, especially Chironomidae and Ephemeroptera, made up almost 40% of its food, on the average. McPhail and Lindsey (1970) reported that spottail shiners from extreme northwestern North America contained insect larvae and masses of filamentous algae. Studies in Minnesota (Smith and Kramer 1964) and Iowa (McCann 1959) indicated that algae, crustaceans (especially cladocerans), aquatic insects, and even eggs and larvae of their own species may, at times, be significant food items. In general, smaller fish ate smaller organisms and small cladocerans were more important to young spottails. Only the larger spottails, especially those over 4.3 inches (110 mm) long, ate their own eggs and young.

The spottail minnow is a forage fish of considerable importance for it is eaten by almost all predaceous fishes (including large spottails) and thus shares, with the emerald shiner, the distinction of being one of the most important forage cyprinids in Canadian lakes. Precise documentation of the extent of predation is scanty although some is provided in the writings of the late Dr D. S. Rawson and others.

Spottail minnows may be infected by a variety of parasitic trematodes, cestodes, nematodes, and protozoans, details of which were provided by Bangham and Hunter (1939) for Lake Erie and Bangham (1955) for Lake Huron. McCann (1959), in a review of spottails in Clear Lake, Iowa, noted that parasitism there was light compared to reports by Bangham.

Bangham and Hunter noted that over half of the 58 Lake Erie specimens examined were infected with *Ligula intestinalis*, which they regarded an exceptionally high percentage, possibly related to the fact that the infected specimens were usually collected near colonies of terns which have been reported as definitive hosts. Lawler (1964) demonstrated infections of 12.5–69.0% of spottails sampled in Heming Lake, Man., and ascribed the differential infections to proximity to fish-eating birds. *See* Hoffman (1967) for his complete list of parasites infecting this minnow in North American waters.

Relation to man The spottail shiner is an important minnow in many parts of its range and is the most frequently used bait minnow in many parts of northern Ontario. In Iowa it is said to be the preferred bait for walleyes. Since it seems to prefer large bodies of water in the southern parts of the Canadian range, it may not be suited to pond culture techniques, but we know of no serious attempts to rear it under artificial conditions.

Nomenclature

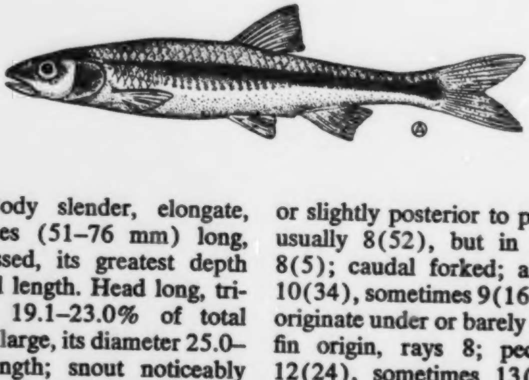
Clupea hudsonia	— Clinton 1824: 49 (type locality Hudson River)
Cyprinus (*Catastomus*) *Hudsonius* (LeSueur)	— Richardson 1836: 112
Luxilus selene	— Jordan 1877a: 60
Minnilus selene	— Jordan and Gilbert 1883a: 188
Notropis scopiferus	— Eigenmann and Eigenmann 1893a: 153
Opsopoeodus borealis	— Harper and Nichols 1919: 266
Hudsonius hudsonius (DeWitt Clinton)	— Jordan, Evermann, and Clark 1930: 132
Notropis hudsonius (Clinton)	— Scott 1967: 62

Etymology *Notropis* — back; keel; *hudsonius* — name from Hudson River.

Common names Spottail shiner, spawneater, shiner, spottail minnow, spottail, spot-tail minnow, sucking carp. French common name: *queue à tache noire*.

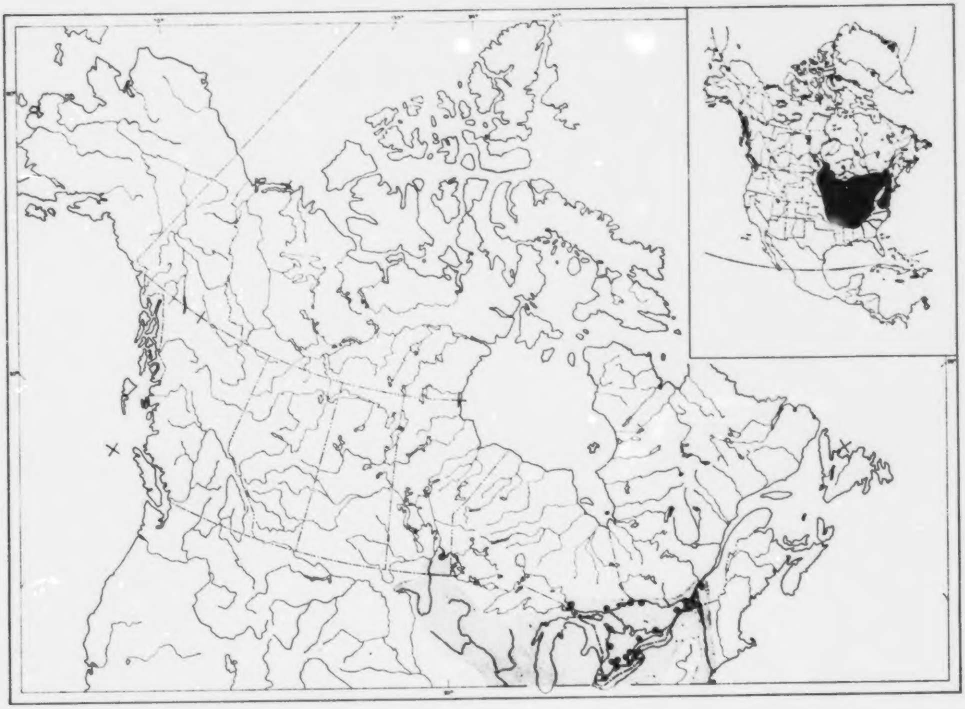
ROSYFACE SHINER

Notropis rubellus (Agassiz)



Description Body slender, elongate, averaging 2–3 inches (51–76 mm) long, moderately compressed, its greatest depth 14.0–18.8% of total length. Head long, triangular, its length 19.1–23.0% of total length; eye relatively large, its diameter 25.0–36.3% of head length; snout noticeably pointed, its length 27.2–36.3% of head length; interorbital wide, its width 27.2–37.0% of head length; mouth large, terminal, premaxillary terminating at a point below nostrils; pharyngeal teeth, slender, slightly hooked, 2,4–4,2; 2,4–4,1; 1,4–3,0; 1,2–1,1. Fins: generally clear; dorsal 1, its origin over or slightly posterior to pelvic fin origin, rays usually 8(52), but in Manitoba 7(5) or 8(5); caudal forked; anal 1, rays usually 10(34), sometimes 9(16) or 11(11); pelvics originate under or barely in advance of dorsal fin origin, rays 8; pectoral rays usually 12(24), sometimes 13(11), rarely 11(4) or 14(1). Scales, cycloid, pigment often concentrated at scale margins giving scales appearance of being dark edged, even below lateral line, 38–45 in lateral line; lateral line complete. Peritoneum silvery. Vertebrae 37–41, usually 39.

Nuptial tubercles on breeding males, fine,



like sandpaper, on head and some predorsal scales and on rays of upper surface of pectoral fins.

Colour The normal colouration is silvery but olivaceous dorsally and silvery white ventrally. Fins transparent. Breeding males have an orange-red colour on the entire head, at least to the nape, and a lighter red on the belly. Colour on breeding females paler than on males. Pigmentation on sides usually bordered below by lateral line.

Distribution The rosyface shiner occurs in eastern and central North America, from Virginia north to New York on the east and Oklahoma and Kansas on the west, and north in the Mississippi drainage to Wisconsin and southern Canada.

In Canada the rosyface occurs from the St. Lawrence River drainage at least to Rivière Nicolet (eastern Lac St. Pierre) westward through the upper St. Lawrence and the lower Ottawa River, through the lower Great Lakes and Lake Huron and extreme eastern Lake Superior and their tributaries, then west only in the Red River in southern Manitoba.

Biology There appear to have been no studies on the biology of Canadian populations of this shiner and any mention of it in the literature is usually limited to records of occurrence. It is more widely distributed in the United States, where some aspects of its biology have been documented.

Pfeiffer (1955) reported on a population in New York State that spawned from June 23 to June 28, in shallow water over gravel at the side of a riffle. The temperature during spawning ranged from 79° to 84° F (26.1°–28.9° C). The release of eggs and sperm occurred over depressions in the gravel and were accompanied by violent vibrations of the spawning fish. Pfeiffer observed that the schools broke up into spawning groups of 8–12 shiners in which the sexes crowded one another, but the sex composition of the groups could not be determined. The actual spawning act seemed to last for 5 or 6 seconds. The author collected newly hatched fry, 5 mm long, 8 days after spawning was first observed. However, within a few days the fry were difficult to find in the gravel and those that were collected and placed in a jar containing gravel immediately worked their way vertically into the gravel as far as possible.

In a report of spawning in Pennsylvania waters Reed (1957a) noted that spawning occurred first over the nests of *Nocomis* spp. and continued later in shallow riffles. In this case spawning commenced on May 26 and continued until June 25. The later spawning involved smaller groups of fish and a predominance of males although the early spawnings involved sexes in about equal numbers. Reed also noted that the temperature range during spawning in 3 successive years was 68°–72° F (20.0°–22.2° C).

The developmental stages of the rosyface are not fully described but Reed (1958) listed the time sequence between the major developmental stages and said that hatching required 57–59 hours at 70° F (21.1° C). Fish (1932) figured a young rosyface 15 mm long.

In the New York State study, 1-year-old females contained 450 eggs and 3-year-olds contained as many as 1482. Eggs obtained immediately after release into the water average 1.5 mm in diameter, but before contact with water and subsequent swelling, the diameter is 1.2 mm.

Reed (1954) described a case of hermaphroditism in three 2-year-old specimens from Pennsylvania, and two of these contained mature eggs and sperm.

Hybrids involving *N. rubellus* and *N. cornutus* are rather well known in United States waters and Bailey and Gilbert (1960) discussed a case of hybridization between *rubellus* and *volucellus*. However, we are not aware of hybrids involving *rubellus* described from Canadian waters.

Pfeiffer found that age determinations could be made using scales. Both sexes live to age 3, but there is evidence that fewer males than females attain this age. The largest female measured about 3 inches (75 mm) standard length, the largest male 2.8 inches (71 mm).

The rosyface shiner seems generally to prefer the flowing water of streams and rivers to the quiet, still waters of lakes and ponds. It seems to occur most often in the lower portion of a stream, especially over fine gravel or sand, just before its confluence with a larger stream or river. It is quite intolerant of turbidity and it seems to us that it is less common in parts of its range than it was 20–30 years ago, but direct evidence is lacking. It is significant, however, that Trautman (1957) noted that its Ohio range had been greatly reduced. He noted in Ohio it was intolerant of turbid waters and bottoms covered with silt. Marked decreases in abundance were observed in several stream sections which had become increasingly turbid and silted.

In the New York State study, aquatic insect forms dominated in the diet, supplemented by terrestrial insects. Reed (1957b) reported the results of a detailed study of food in Pennsylvania waters and concluded that the rosyface was omnivorous during most of the year, consuming aquatic insects (71.9%), algae, diatoms (18.1%), and inorganic material (10%). Caddisfly larvae were the most important single item, constituting 23.7% of the diet.

Bangham and Hunter (1939) found no parasites in the one specimen of rosyface shiner (which they called *N. rubrifrons*) examined from the western end of Lake Erie.

Hoffman (1967) listed various species of trematodes and one species of nematode (*Spiroxys* sp.) as parasites of this minnow in North American waters.

Relation to man Although direct evidence is lacking, it seems unlikely that the rosyface shiner is of direct importance as a forage or prey species for game fishes. Its sensitivity to turbidity, however, may make it useful in studies of water quality deterioration.

Nomenclature

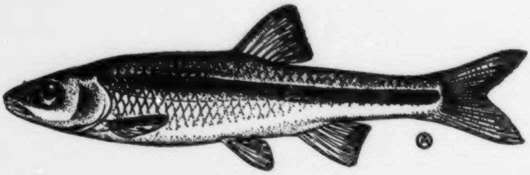
Alburnus rubellus — Agassiz 1850: 364 (type locality Sault Ste. Marie, Lake Superior)
Alburnus rubrifrons — Cope 1865: 85
Notropis rubrifrons (Cope) — Jordan and Evermann 1896–1900: 295
Notropis rubellus (Agassiz) — Hubbs and Brown 1929: 34
Photogenis rubrifrons Cope — Hubbs and Brown 1929: 35

Etymology *Notropis* — back; keel; *rubellus* — reddish.

Common names Rosyface shiner, rosy-faced shiner. French common name: *tête rose.*

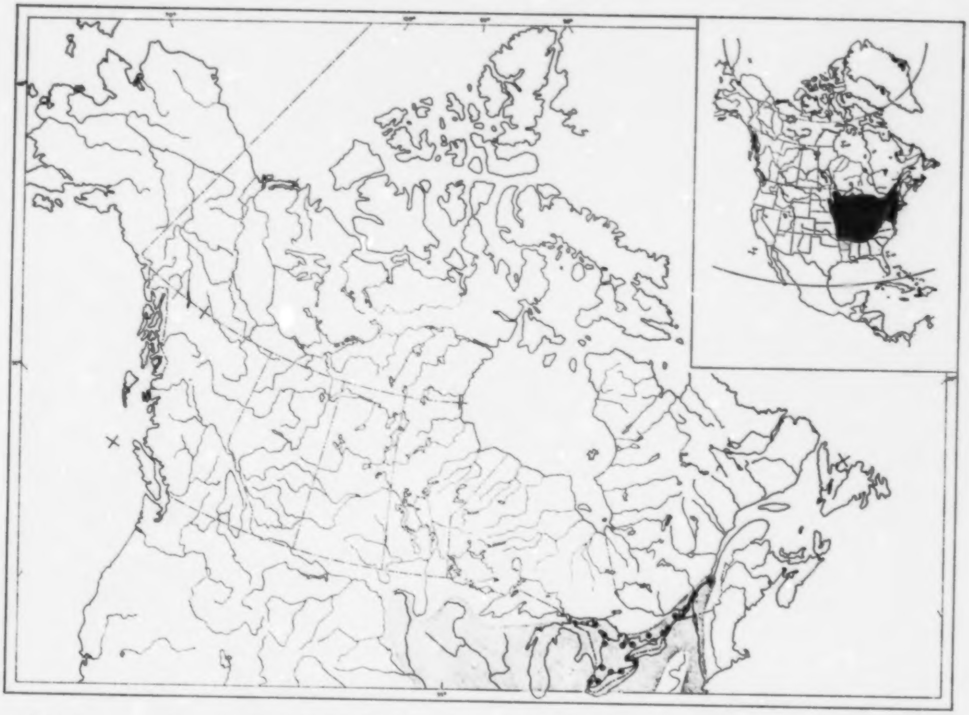
SPOTFIN SHINER

Notropis spilopterus (Cope)



Description Body compressed laterally, large adults (3 inches or 76 mm total length) noticeably deep bodied, greatest depth 16.6–22.8% of body length. Head noticeably pointed, its length 19.0–23.1% of total length; eye diameter 23–33% of head length; snout long and rather sharp, its length 23–40% of head length; interorbital wide, its width 29.1–45.0% of head length; mouth subterminal, slightly overhung by pointed snout, premaxillary terminating below posterior margin of nostril; pharyngeal teeth short, broad, slightly hooked, 1,4–4,1 or 1,4–4,0. Fins: dorsal 1, well developed, high and with distinctive black pigment on membrane between fin rays, particularly on membrane between posterior 3 rays, dorsal rays 8, seldom 7; caudal distinctly forked; anal 1, well developed, but without dark pigment, rays usually 8(22), occasionally 7(2) or 9(2); pelvic rays usually 8(17), occasionally 9(6), rarely 7(1); pectoral rays usually 13 or 14, occasionally 12 or 15. Scales cycloid, large, usually about 39 in lateral line but range is 35–41; lateral line complete. Peritoneum silvery. Vertebrae 37–39.

Nuptial tubercles on breeding males relatively large and pointed, on top of head, and extending posteriorly along nape in a narrow band to origin of dorsal fin, a few also on lower jaw; smaller tubercles also on leading edge of pectoral fin, on anal rays, and on scales, especially posterior margins on flanks above and anterior to the anal fin.



Colour The overall colouration is silvery. Breeding males, especially, have a steel-blue sheen or cast dorsally, less so laterally, becoming silvery white below and with yellowish lower fins. The most characteristic marking is the concentration of black pigment on the membrane between the last three rays of the dorsal fin. Preserved specimens usually exhibit a broad lateral band only on the posterior half of the body.

Distribution The spotfin shiner occurs from Oklahoma and Alabama north to New York State and southern Quebec, west through Great Lakes basin to North Dakota.

In Canada it occurs from the St. Lawrence River in the vicinity of Quebec City west, including Lake Champlain and the lower Ottawa River, to the tributaries of lakes Ontario, Erie, and St. Clair. It appears to be more numerous in rivers than in lakes.

Biology The biology of this species in Canadian waters has not been studied and, hence, the following details are derived from studies in the United States where the species has a much wider range. In New York State, Stone (1941) noted that spawning took place from the latter part of May to mid-August, the peak of the spawning varying with the locality. Place of spawning apparently depends on current strength, depth, and availability of underwater objects, for the eggs are adhesive and are laid on the underside of submerged logs and roots. The same author reported egg counts of 225–1580 using 14 specimens. Stone also noted that the scales had well-marked annuli and could be used for age determination. The oldest spotfins used in his studies were in their fifth year; the largest male 4.2 inches (108 mm) the largest female 3.7 inches (93 mm) The largest specimens examined by us were from Ontario and measured 2.8–3.2 inches (70–80 mm).

Although not a common species anywhere in southern Canada, the spotfin occurs more frequently in large rivers than in lakes, where we have seined it over clean sand and gravel substrate, often in somewhat turbid waters.

The spotfin shiner is reported to be mainly insectivorous, feeding on terrestrial and aquatic insects.

Although the species doubtless falls prey to larger carnivorous fishes on occasion, we have no information on their utilization as forage fishes.

Bangham and Hunter (1939) examined 58 specimens of the species, which they called *N. whipplii*, and noted 29 lightly infected variously with trematodes, a cestode, nematodes, and a leech, *Piscicola punctata*. Hoffman (1967) listed only one species of trematode, *Posthodiplostomum minimum*, and a cestode, *Proteocephalus* sp., from the spotfin shiner in North American waters.

Relation to man The spotfin is of no real importance as a bait or forage fish because of its limited distribution, but wherever it occurs in sufficient numbers it would undoubtedly be a desirable bait species.

In the United States it has attracted attention as a bait species and Stone (1941) noted that it could be readily propagated in ponds. Lewis and Gunning (1959) noted additional features of southern Illinois populations that enhanced the value of the species as bait.

Nomenclature

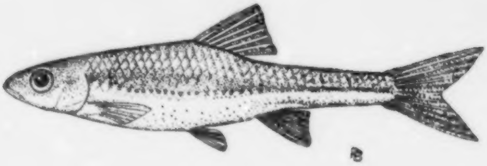
Photogenis spilopterus — Cope 1869: 378 (type locality St. Joseph River, Michigan)
Hybopsis fretensis — Cope 1869: 382
Notropis whipplii — Evermann and Kendall 1902: 212
— Halkett 1913: 64
Notropis whipplii spilopterus — Hubbs and Greene 1928: 381
— Hubbs and Brown 1929: 33
— Greeley 1930: 80
— Greeley and Greene 1931: 88
— Hubbs and Cooper 1936: 61
— Greeley 1940: 74
Notropis spilopterus — Radforth 1944: 60
— Dymond 1947: 21
— Legendre 1952: xi
— Gibbs 1957: 187

Etymology *Notropis* — back; keel; *spilopterus* — *spilos*, meaning spot, and *pter*, meaning wing or fin.

Common names Spotfin shiner, silver-finned minnow, satin-finned minnow. French common name: *méné bleu*.

SAND SHINER

Notropis stramineus (Cope)



Description Body small, averaging 2–3 inches (51–76 mm) long, slender, somewhat compressed, but body not deep, greatest depth usually 13–18% of total length. Head length 18.7–21.7% of total length; eye moderate, diameter 30.0–33.3% of head length; snout length about equal to eye diameter, 30.0–33.3% of head length; interorbital wide, its width 34.6–44.4% of head length; mouth small, terminal or nearly so, upper jaw extending to below posterior nostril; pharyngeal teeth 0,4–4,0. Fins: dorsal 1, rays usually 8; caudal forked; anal 1, rays nearly always 7, rarely 6, never 9; pelvics originating under dorsal fin origin, rays usually 8; pectorals short, broad, rays 12–16, usually 13(13), or 14(7), sometimes 12(3), 15(4), or 16(3). Scales cycloid, large, 34–39 in lateral line; lateral line complete. Peritoneum silvery, lightly speckled. Vertebrae 33–36, usually 35.

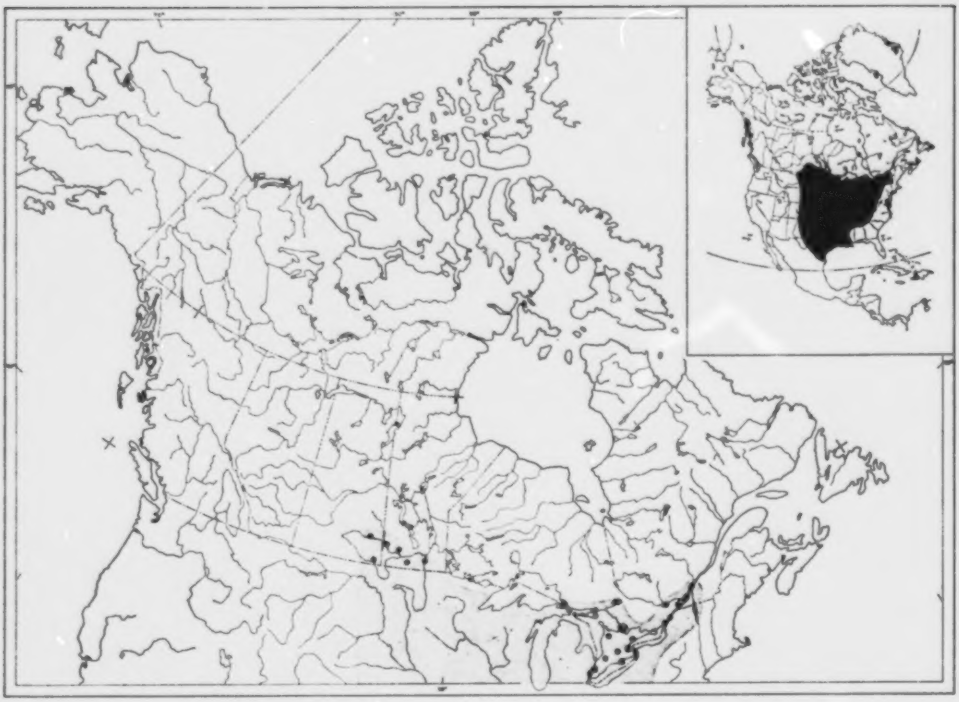
Nuptial tubercles microscopic on heads of breeding males.

Colour Overall colouration silvery with straw-coloured tints. Outlines of scales clearly visible on the back, scales large, not crowded in predorsal region. A thin but distinct mid-dorsal stripe from nape to posterior caudal peduncle, with small concentration of pigment at anterior and posterior base of dorsal fin. Dark lateral band present posteriorly, weak anteriorly and more or less restricted to concentration of melanophores surrounding the lateral line pores. The illustrations of melanophore distribution on head and caudal region presented by Suttkus (1958) are not entirely applicable to Canadian specimens examined by us. Hubbs and Greene (1928) were the first to note that *stramineus* is usually paler northward than its close relative *volucellus*, particularly after preservation, an observation with which we are in complete accord.

Systematic notes The scientific status of the sand shiner has long been confused. The species was known as *Notropis blennius*, then as *Notropis deliciosus*, and finally as *Notropis stramineus*. The early nomenclatural history of the species was thoroughly discussed by Hubbs and Greene (1928) whose informal and critical comments should be of special interest to Canadian students. Trautman (1957) noted that the confusion was such that publications prior to 1928 are of little value. The form reported from Big Creek, Elgin County, Ont., by Hubbs (1926) as *Notropis deliciosus deliciosus*, was shown by Hubbs and Greene (1928) to be *Notropis volucellus*. Again, Dymond (1926) presented systematic and biological information on "*Notropis deliciosus stramineus*" in Lake Nipigon but later re-examination disclosed that the specimens were, in fact, *Notropis volucellus* (Dymond 1944b).

More recently, the status of the species and its subspecies in the northern portion of its United States range was discussed by Bailey and Allum (1962).

The necessity of the change to *Notropis stramineus* was the subject of a thorough



review by Suttkus (1958). Currently, at least two subspecies are recognized, *N. s. stramineus* (Cope), the northeastern sand shiner, and *N. s. missuriensis*, a smaller-scaled type.

Subspecific assignations of Canadian populations seem meaningless in light of the present lack of knowledge.

Distribution The sand shiner occurs through central and southern North America, from the upper St. Lawrence and Lake Champlain region, south in New York and Pennsylvania to the Gulf of Mexico drainage (west of the Mississippi) to northeastern Mexico, and north through the Great Plains to southeastern Saskatchewan.

In Canada it occurs from about Lac St. Pierre of the upper St. Lawrence River, through the Great Lakes drainage of Ontario including extreme eastern Lake Superior. There are no Ontario records west of eastern Lake Superior but it occurs in the Red–Assiniboine River system of southern Manitoba and Saskatchewan.

Biology Few studies have been conducted on the biology of the sand shiner, none on Canadian populations. A recent study by Summerfelt and Minckley (1969) concerns the southern subspecies, *N. s. missuriensis* in Kansas, and hardly seems applicable to Canadian populations. Also, since the species was for many years misidentified, little dependence can be placed on Canadian literature, even that which listed the species under its previous name, *N. deliciosus*. In Iowa spawning occurs in June, July, or August, and the eggs are scattered over clean gravel or sand (Carlander 1969).

Starrett (1951) reported that in Iowa, age 1 females contained about 250 eggs; age 2, 1100 eggs and age 3, 1800 eggs.

Collections in Ontario waters suggest that sand shiners prefer sandy shallows of lakes and large rivers, often where there is sparse growth of rooted aquatic plants.

Food studies on Iowa populations indicated that sand shiners feed on aquatic and terrestrial insects, and bottom ooze diatoms and, in the absence of data, we assume that food preferences in Canadian populations are similar.

Bangham and Hunter (1939) reported the results of examination of 12 specimens from eastern and western Lake Erie. Trematodes, cestodes, and protozoan parasites were identified but, generally speaking, the degree of infection was low.

Hoffman (1967) listed nine species of trematodes, and one crustacean from sand shiners in North American waters.

Relation to man This small and relatively hardy minnow is not uncommon in suitable habitats but it is seldom recognized and, even in collections, is often misidentified. It must serve as a rather important forage species but, because it is difficult to identify, is seldom recognized in stomach contents.

Gould and Irwin (1965), in reference to southern populations, noted that sand shiners were good bioassay animals because they were easy to transport, withstood low oxygen conditions, and would take dry food readily.

Nomenclature

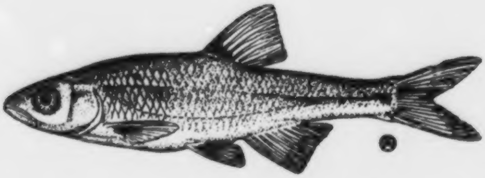
Hybognathus stramineus	— Cope 1864: 283 (type locality Detroit River, Grosse Isle, Mich.)
Notropis phenacobius	— Forbes 1885: 137
Notropis reticulatus	— Eigenmann and Eigenmann 1893a: 152
Notropis deliciosus stramineus (Cope)	— Hubbs and Lagler 1941: 59
Notropis deliciosus (Girard)	— Radforth 1944: 73
	— Dymond 1947: 21
Notropis stramineus (Cope)	— Suttkus 1958: 313

Etymology *Notropis* — back, keel; *stramineus* — made of straw.

Common names Sand shiner, shore minnow, straw-coloured minnow. French common name: *méné paille*.

REDFIN SHINER

Notropis umbratilis (Girard)



Description Body small, less than 2.5 inches (64 mm) total length, compressed laterally, its greatest depth 18.1–24.5% of total length; head appears short, its length 19.4–22.0% of total length; eye diameter 25.0–34.7% of head length; snout blunt, its length 27.2–36.3% of head length; interorbital broad, its width 28.5–40.0% of head length; mouth relatively large, terminal, premaxillary terminating below posterior margin of nostril; pharyngeal teeth slender, not obviously hooked, 2,4–4,2. Fins: transparent; dorsal 1, its origin slightly posterior to origin of pelvics, the anterior base conspicuously suffused with black pigment, rays 8(34), rarely 7(1); caudal distinctly forked; anal 1, rays usually 11(20), occasionally 10(6) or 12(5); pelvics originate slightly in advance of dorsal origin, rays usually 8(22), rarely 7(1) or 9(1); pectorals reaching almost to pelvic fin origin, rays 12(13) or 13(11). Scales cycloid, small, 39–46 in the lateral line; lateral line somewhat decurved, complete. Peritoneum silvery with speckles. Vertebrae 35 or 36.

Nuptial tubercles on breeding males, very fine, on head and muzzle, extending onto nape in a narrow band to dorsal fin origin, also in 2 rows on each side of mandible, not apparent on lower fins or flanks above anal fin. (*See* figures in Trautman 1957.)

Colour A silvery minnow with clear fins; anterior base of dorsal fin suffused with dark pigment, not forming a spot, but whole base dark; sides speckled with pigment; during spawning males become darker overall, steel-blue on sides, although caudal and anal fins take on a distinct reddish hue and paired fins may also have a slight reddish cast.

Systematic notes Canadian populations lie within the range of the subspecies *N. u. cyanocephalus* (Copeland).

Distribution The redfin shiner occurs rather widely in the southern portion of the Great Lakes watershed and south in the Mississippi River system, from New York and Pennsylvania west to southern Minnesota, south to Louisiana and Texas.

In Canada it is known to occur in only a few streams of southern Ontario: Black Creek near Marburg, Norfolk County, a tributary of Lake Erie; Thames River, Essex County; Sydenham River, Middlesex County; Ausauble River, Lambton County; and the Saugeen River, Bruce County.

Biology There are only a few localities in Ontario where the redfin shiner thrives, but such populations have either not been studied or, if studied, not reported except for reports of occurrence. Dates of spawning in Ontario are not known but observations of Norfolk County populations suggest that spawning takes place in July and August. Eleven adult females taken in Black Creek on August 15, 1946, contained large eggs and were presumably spawning; males taken at the same time displayed vivid spawning colours. Trautman (1957) recorded spawning over sand and gravel bottoms in slow-moving sections of streams and our limited observations suggest similar behaviour.

Hunter and Hasler (1965) described reproductive behaviour of the species in pools or ponds of the University of Wisconsin Arboretum. Redfin shiners used the nests of the green sunfish for spawning sites and the authors suggested that this may be regular procedure when such nests are available and being used by the sunfish. They are not used if the sunfish are not spawning, suggesting that the minnows are attracted by sexual fluids of the sunfish. Water temperature differences in the Canadian environment may prevent such close ecological associations.

When not spawning, redfin shiners are reported to prefer the clear, quiet waters of weedy pools, where submerged and emergent vegetation abound.

Bangham and Hunter (1939) found no parasites in the 13 specimens examined from the eastern end of Lake Erie.

Relation to man The small size, attractive colours, and tolerance of quiet, weedy waters combine to make the redfin a potential aquarium species, and its reproductive behaviour suggests that much could be learned from aquarium-based studies. We have no evidence of Canadian economic significance for it is too small and uncommon to be a useful bait or forage species at the present time. In some parts of the United States, such as Iowa, the redfin is used extensively for bait.

Nomenclature

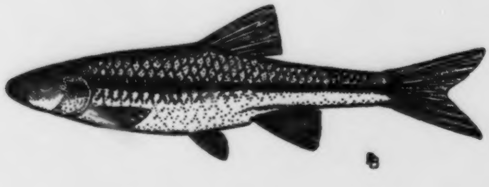
Alburnus umbratilis — Girard 1857a: 193 (type locality Arkansas)
Lythrurus umbratilis (Girard) — Jordan, Evermann, and Clark 1930: 125
Notropis umbratilis — Scott 1967: 65

Etymology *Notropis* — back; keel; *umbratilis* — from *umbro*, meaning to shade.

Common names Redfin shiner. French common name: *méné d'ombre*.

MIMIC SHINER

Notropis volucellus (Cope)



Description Body small, average size 2–3 inches (51–76 mm) long, slender, somewhat compressed but body not deep, greatest depth usually 13.5–16.3% of total length. Head length 18.8–21.8% of total length; eye moderate, diameter 28.5–38.0% of head length; snout length somewhat less than eye diameter, 27.2–34.7% of head length; interorbital wide, its width 27.2–36.3% of head length; mouth small, terminal or nearly so, upper jaw extending to below posterior nostril; pharyngeal teeth 0,4–4,0. Fins: dorsal 1, rays usually 8; caudal forked; anal 1, rays nearly always 8, rarely 9, pelvics originate below dorsal fin origin, rays usually 9(29) seldom 8(9), rarely 10(2); pectoral fin rays usually 12(7), 13(7), 14(10), or 15(15), rarely 16(1). Scales cycloid, large, 36–39, usually 37 or 38; lateral line complete. Peritoneum silvery, lightly speckled. Vertebrae 34–37, usually 36.

Nuptial tubercles on breeding males, microscopic, on top of head, densely clustered on snout, sparse on preopercle and lower surface of head.

Colour Overall colouration silvery (less straw coloured than *N. stramineus*). Outlines of scales clearly visible on back, scales large, not crowded in predorsal region. No distinct dorsal stripe. Dark lateral band evident posteriorly, becoming vague and ill-defined from below dorsal fin, anteriorly; lateral band expanded in tail region more or less, as illustrated by Suttkus (1958). Black pigment about anus and at base of anal fin. Canadian specimens are noticeably darker than *N. stramineus*, especially after preservation in formalin solution (*see N. stramineus*).

Systematic notes *Notropis volucellus* and *N. stramineus* present more difficulties in identification to Canadian students than any other group of fishes except the coregonines (*Coregonus* spp.). *See N. stramineus* for confusion with that species, and *see also* Hubbs and Greene (1928) for a discussion of its similarity to *N. stramineus* (= *deliciosus*).

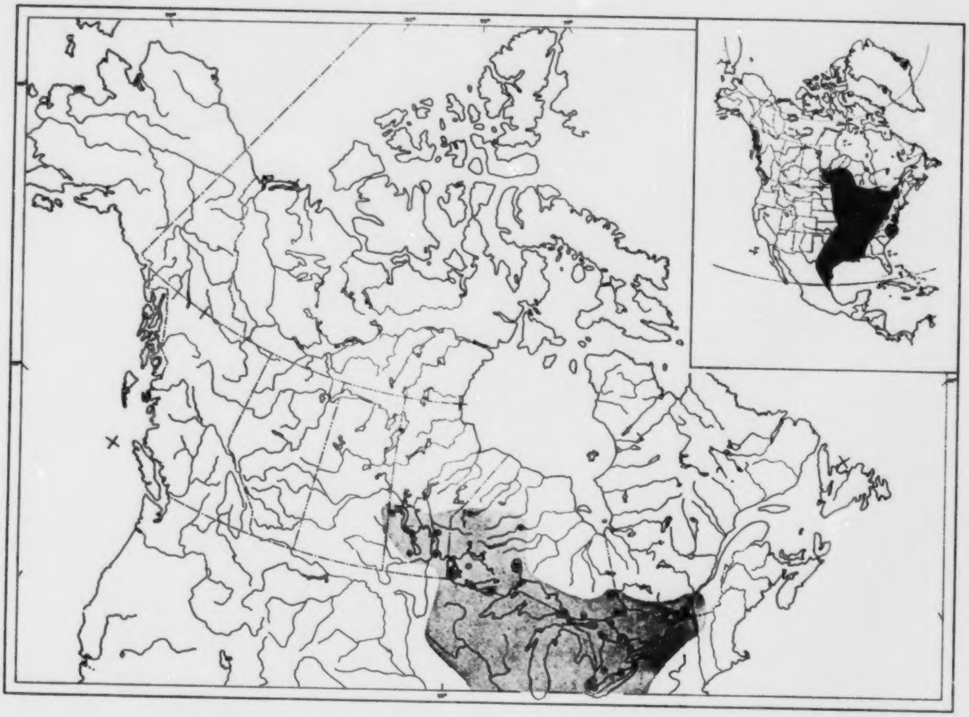
Subspecies have been described (Hubbs and Greene 1928; Trautman 1931), and the typical subspecies *N. v. volucellus*, the northern mimic shiner, was said by Hubbs and Lagler (1958) to be the form occurring in Canada. However, the taxonomic relationships of the mimic shiner throughout its range have not been studied and, hence, the assignation of subspecific designations to the even lesser-known Canadian populations seems unwarranted at this time. The form occurring in Big (or Talbot) Creek, Elgin County, Ont., was considered by Hubbs and Greene (1928) to be an aberrant form, which they once assigned to the subspecies *N. v. buchanani* Meek, but which later (Hubbs and Lagler 1958) has been regarded as an aberrant form of *N. volucellus*.

Distribution The mimic shiner ranges from the upper St. Lawrence River on the northeast, southwest to northern Alabama and the Gulf coast states to Texas; in the Mississippi valley north through Missouri and Iowa and all the Great Lakes states to Manitoba.

In Canada it occurs from tributaries of Lac St. Pierre (Nicolet, Saint-Francois, and Yamaska rivers) west through the Great Lakes and tributaries, north in Ontario to Attawapiskat and Sandy lakes, west through Rainy River and Lake of the Woods to Manitoba, where its northern limit was noted by Keleher (1956) to be Fishing Lake on the Manitoba–Ontario boundary at about 52° N. In Ontario and Manitoba the mimic shiner reaches its northern limit between the 60° F (15.6° C) and 65° F (18.3° C) July isotherms.

Biology The problems of identification have been partly responsible for the absence of studies on the biology of the mimic shiner. Dymond (1926) presented the only available detailed account of morphometric and meristic data (under the name *N. deliciosus stramineus*) in a comprehensive study of Lake Nipigon fishes, but provided little information on its biology. Dymond's introductory sentence in the Lake Nipigon account, "This is one of the most insignificant of the minnows, both in size and appearance," perhaps also helps to explain why it has been ignored.

In the only study of the life history known to us, Black (1945) worked with the mimic shiner in Shriner Lake, Ind. He was unable to determine when or where spawning



occurred but speculated that it possibly took place at night and perhaps the eggs were broadcast over aquatic vegetation at depths of 15–20 feet. In the year of study all females examined were ripe by June 20, most were partly spent by July 9, and nearly all were spent by July 24. Study of 103 gravid females (preserved) yielded an average egg number of 367 per female. Black considered that the fish attained 2 years of age (by size groups).

Various authors note that the mimic shiner seems to prefer quiet or still water. Black also remarked on the peculiar movements of the species; for example, that the schools move offshore before dark, then break up, and individuals could not be captured in shore seining after dark, and repeated efforts by trawling in deeper water yielded only four specimens.

Black examined the stomach contents of over 500 shiners and concluded that the most important foods in Shrine Lake, Ind., were entomostracans (especially *Daphnia*), insects (particularly Chironomidae), and green and blue-green algae.

In turn, the mimic shiner was eaten by a variety of predators, fishes and birds, but particularly largemouth and smallmouth bass.

The parasites harboured by mimic shiners in Lake Erie and Lake Huron (and Manitoulin lakes) have been reported by Bangham and Hunter (1939) and Bangham (1955) respectively. Black (1945) also reported *Ligula* and a sporozoan parasite of the genus *Myxobolus*. From these studies, and the comments of the authors, one would conclude that the mimic shiner seems to carry a relatively small parasite fauna, involving mainly trematodes, cestodes, and nematodes.

Hoffman (1967) listed six trematodes, one nematode, and a crustacean in specimens from North America waters.

Relation to man Based on the number and size of the collections in museums, and the statements of a few observant collectors, the mimic shiner is (or was) common in parts of the upper St. Lawrence River system (Toner 1937; Cuerrier et al. 1946), and in some regions of southern Ontario. It undoubtedly forms a part of the diet of predators, such as smallmouth bass. There are no direct observations, but when abundant, its contribution would be significant. Its value as a bait minnow in our area is unknown since the species is seldom recognized either by bait dealers or investigating biologists.

Nomenclature

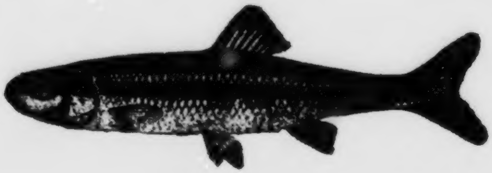
Hybognathus volucellus	— Cope 1864: 283 (type locality Detroit River, Grosse Isle, Mich.)
Notropis deliciosus stramineus	— Dymond 1926: 50
Hybopsis volucella (Cope)	— Jordan, Evermann, and Clark 1930: 133
Notropis volucellus (Cope)	— Scott 1967: 70

Etymology *Notropis* — back; keel; *volucellus* — a diminutive, from *volucer*, winged or swift.

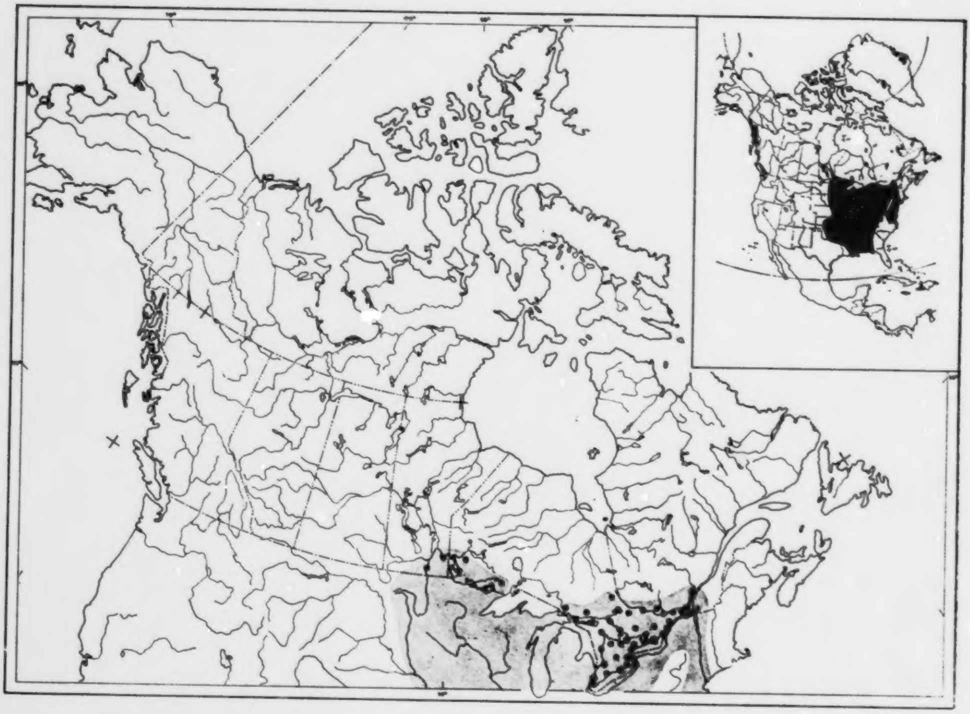
Common names Mimic shiner. French common name: *méné pâle*.

BLUNTNOSE MINNOW

Pimephales notatus (Rafinesque)



Description Body elongate, tubular, average length 2.5 inches (64 mm), not strongly compressed laterally, and body not deep, its greatest depth 14.5–20.4% of total length. Head broad, bluntly triangular, and small, its length 18.1–21.4% of total length; eye moderate, its diameter 25.0–37.5% of head length; snout rounded, blunt (hence name), slightly overhanging upper lip, its length 25.0–36.3% of head length; interorbital broad, its width 35.2–50.0% of head length; mouth, inferior, overhung by rounded projecting snout, gape not reaching front of eye; a thickened papillalike protuberance at each corner of mouth of large breeding males; pharyngeal teeth 0,4–4,0. Fins: all fins transparent in young, olive in adults; dorsal 1, its origin slightly behind pelvic fin origin, rays 8(44); caudal rather shallowly forked and rounded; anal 1, relatively small, its origin



below tip of depressed dorsal, rays 7(43), rarely 8(1); pelvics originate slightly in advance of dorsal fin origin, rays 8(33); pectorals small, rays usually 15(16), or 16(14), rarely 14(1), or 17(1). Scales cycloid, small, and crowded predorsally; lateral line complete, lateral line scales 42–50. Peritoneum uniformly black; intestine elongated. Vertebrae 37 or 38.

Nuptial tubercles large, sharp, and in 3 rows across the snout of males, not extending above the nostrils; many small tubercles may also occur on dorsal surface of anterior pectoral rays.

Colour Back olive-green, to brown, silvery on sides and silvery white below. Fins with yellowish or olive tint. The scales have a dark edge, which imparts a crosshatched appearance to young fish. A conspicuous black spot at base of caudal fin. A dark lateral band extends from caudal spot to eye. Both caudal spot and lateral band most evident on preserved specimens, which often have a rusty tinge above anterior portion of lateral band immediately behind head.

Breeding males are very dark, almost black; even the fins, particularly dorsal fin, suffused with dark chromatophores.

Distribution The bluntnose minnow occupies a broad range through central North America including the Mississippi and Great Lakes drainage systems. It occurs in lakes, ponds, rivers, or creeks from southern Quebec and Lake Champlain south in the Hudson valley to the coast and to Virginia; southwest to the Gulf states and north through the Mississippi drainage system to the Great Lakes, and southeastern Manitoba.

In Canada, it occurs in southwestern Quebec, west through the Great Lakes (but only in extreme eastern Lake Superior drainage), and tributary waters, including the Ottawa River and its tributaries, north to Timagami, and west to Lake of the Woods. A rare species in Manitoba, it was reported from only three localities by Keleher and Kooyman (1957): at Winnipeg, St. Andrews Locks on the Red River, and at Echo Lake (50°13′N, 95°22′W).

Biology The spawning habits are well known, perhaps because it builds a nest in shallow water and fights off all intruders, or because it is relatively common in waters adjacent to populated areas. The bluntnose minnow deposits its eggs on the under surface of flat stones, boards, logs, broken tile, bricks, or any other object that offers a suitable lower surface, but it prefers a flat stone or other object resting directly on bottom in 6 inches to 3 feet of water. In spring, the male selects a suitable stone and commences to hollow out a nest beneath it. Using his snout, armed with large nuptial tubercles, he pushes pebbles and other objects out of the way, and removes silt and light material by successive heavy sweeps of his tail. After a shallow depression has been created, the male carefully cleans off the under surface of the overlying stone with his back and mouth. The males do not seek out females and will drive them off if they approach the nest before it is completed. When all is ready to his satisfaction, the male will allow the female to enter. The adhesive eggs are deposited on the cleared underside of the overhanging stone, log, or whatever surface was chosen by the male.

The eggs are large, and measure 1.0–1.5 mm in diameter. One female deposits 200–500 eggs per season. Hubbs and Cooper (1936) observed that individual females would remain in a nest for 10–30 minutes and deposit 25–100 eggs. Successive females would be allowed to enter and deposit their eggs in the nest, which was under constant guard by the male. Hubbs and Cooper reported that the average nest covered 21 square inches and contained 2447 eggs, or 128 eggs per square inch. Most spawning takes place at night (Westman 1938) but some spawning may occur in the daytime (Hubbs and Cooper 1936).

Spawning commences in late May or June when water temperatures are at least 68° F (20° C) and may continue until August in some areas. Fish culturists know that in artificial ponds females may spawn at least twice in a season. Spawning was considered to be prolonged in southeastern Ontario by Toner (1943), who found males with well-developed tubercles from May to August. Observations of nests clearly indicate that not all spawning takes place at one time, for the nests normally contain freshly laid eggs and eggs in an advanced state of development. Westman examined ovaries of 10 females in New York State in April and found the number of eggs varied from 1743 to 2223. The eggs in each female were always in several different stages of development.

Males may build nests literally side by side when a large spawning object is available. Hubbs and Cooper reported that long boards would have one nest for each linear foot.

Westman noted that if the male was removed from the nest, the eggs would die within 12 hours. The male's presence is essential to ensure a continuous flow of water over the eggs and to keep them free of silt.

The eggs hatch in 7–14 days depending upon temperature, the young being about 5 mm long.

The eggs and young have been described in considerable detail by Fish (1932), who provided drawings of developing eggs and young; drawings and descriptions are given for young at lengths of 5 mm (newly hatched), 6 mm (7 days old), and 12 mm.

Westman observed that young bluntnose minnows achieved a standard length of 12 mm 2 weeks after hatching and a length of 37 mm by December. He provided additional evidence indicating that only a small percentage attained a standard length of 55 mm during their first growing season. Females may attain sexual maturity in their second year (i.e., at age 1) but males seem not to mature until the third year (age 2). Length of life is not known but both males and females have been taken in their fourth summer (age 3). Males grow larger than females and may attain a total length of 4 inches (102 mm), females 3 inches (76 mm).

The bluntnose minnow seems to prefer the sand- and gravel- (or occasionally mud-) bottomed shallows of clear lakes and ponds but lives also in a variety of rocky or gravelly streams and creeks. It appears to avoid heavily weeded areas.

The inferior mouth is an adaptation to bottom feeding. Examination of stomach contents revealed that the food consisted almost entirely of organic detritus (bottom ooze) from the bottom (20–50% by volume), chironomid larvae (5–30%), and Cladocera (10–75%), according to Keast and Webb (1966) whose studies were conducted in Lake Opinicon, Ont. Samples from Kearney Lake, Algonquin Park, contained mostly chironomid larvae and algae.

The bluntnose minnow is preyed upon by a wide variety of predators, including its own species, for young nonspawning males will quickly devour the eggs in an unprotected nest. The young are ideal forage for yellow perch, and the young of the sunfishes, rock bass, and other centrarchids that occupy the same habitat. Specific food studies involving the bluntnose are lacking but it is an ideal forage fish for any larger, predaceous species, as it utilizes a food resource not exploited by game fishes.

Bangham and Hunter (1939) examined 13 specimens of the bluntnose minnow from Lake Erie and reported 5 minnows parasitized. Parasites identified were trematodes *Neascus* sp. in the 2 parasitized fish of the 3 taken from the east end of the lake. Trematodes *Lebouria cooperi* and *Neascus vancleavei*, the cestode *Ligula intestinalis*, and Protozoa and Myxosporidia were recorded from west end specimens.

Bangham (1955) found all 17 hosts examined from Lake Huron and Manitoulin Island infected. The trematode *Posthodiplostomum minimum* occurred in 14 of the specimens examined. Other parasites included trematodes, protozoans, and the nematode *Rhabdochona cascadilla*.

Hoffman (1967) listed many species of Protozoa, Trematoda, Cestoda, Nematoda, molluscan glochidia, and the crustacean *Lernaea cyprinacea* from this species in North American waters.

Relation to man The bluntnose minnow is an important forage minnow for game fishes. Although it is used for live bait in Canada, it is not a popular bait species because it does not withstand crowding in a minnow pail as well as other species. It is commonly used as a bait fish in the United States.

The bluntnose can be artificially propagated with considerable success. Cooper (1936a) and Dobie et al. (1956) reported yields of up to 104,800 fish (250 pounds) per acre in Michigan, and 473,350 individuals per acre in Ohio. Artificial nesting sites are provided in ponds by floating boards on the surface or driving shingles into the bank a few inches below water level. Artificially reared bluntnose minnows were widely distributed throughout Ohio where the bluntnose has been widely introduced to ensure an adequate supply of forage minnows as food for game fishes.

Nomenclature

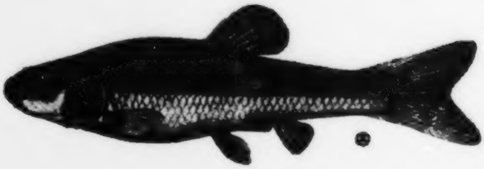
Minnilus notatus — Rafinesque 1820c: 47 (type locality Ohio River)
Hyborhynchus notatus Rafinesque — Hubbs 1926: 48
Pimephales notatus (Rafinesque) — Hubbs and Lagler 1964: 86

Etymology *Pimephales* — fat, head; *notatus* — noted or spotted.

Common names Bluntnose minnow, blunt-nosed minnow. French common name: *ventre-pourri.*

FATHEAD MINNOW

Pimephales promelas Rafinesque

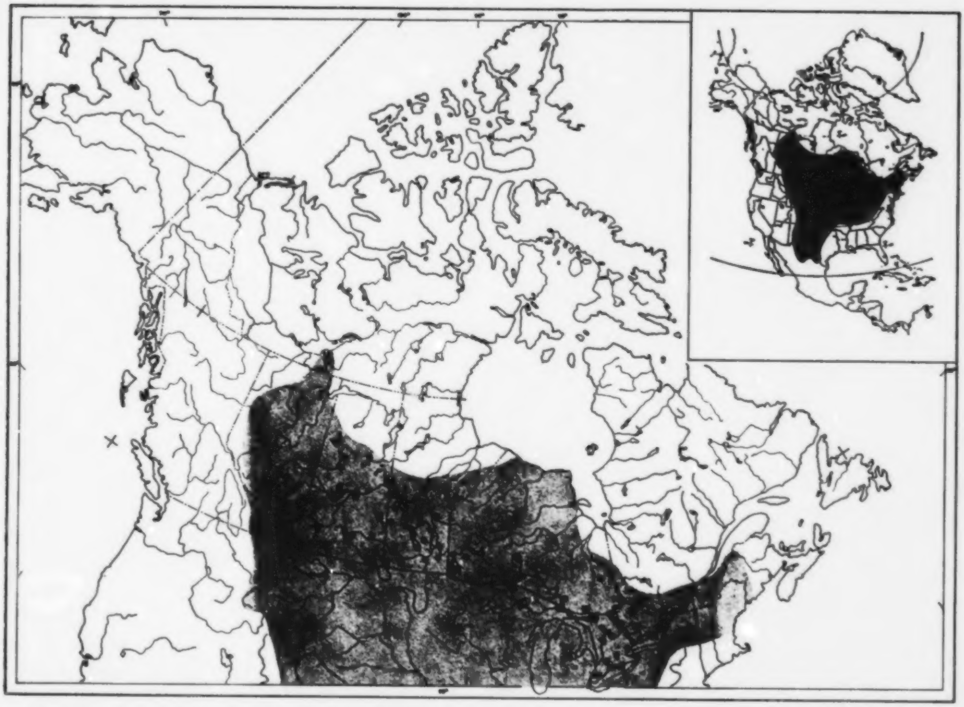


Description Body short, average length about 2 inches (51 mm), thick set, compressed laterally and deep bodied, often with a pronounced belly, body depth 20.0–27.5% of total length. Head rather sharply triangular, its length 20.3–25.0% of total length; eye moderate, not noticeably large, its diameter 18.7–30.0% of head length; snout slightly overhanging upper lip, snout length 24–40% of head length; interorbital broad, its width 33.3–53.8% of head length; mouth small, nearly terminal, snout slightly protruding beyond upper lip, gape not extending to front of eye; pharyngeal teeth 0,4–4,0, slightly hooked. Fins: dorsal 1, its origin over pelvic fin origin, rays always 8(89), first ray short and not tightly bound to second ray, males may have a black spot or blotch on lower third of first 2 or 3 rays; caudal shallowly forked; anal 1, its origin below depressed dorsal fin, rays always 7(89); pelvics small, originating below dorsal origin, usually extending to anal fin origin in males, but not in females, rays always 8(89); pectorals relatively short, rays usually 15(21), or 16(18), sometimes 17(8), rarely 14(1), or 18(1). Scales cycloid, moderate in size; lateral line incomplete, usually terminating below dorsal fin origin or before, scales in lateral series 41–54; some populations, notably those in the Thunder Bay region of Ontario, may have lateral line complete except for 3 or 4 pored scales. Peritoneum uniformly black; intestine long but variable, usually 2.0–2.5 times body length. Vertebrae usually 37(18), sometimes 36(11), seldom 35(3), or 38(3).

Nuptial tubercles on males only, large, well-developed ones on snout that rarely extend beyond nostrils, in three main rows, also a few on lower jaw; sometimes scattered minute tubercles on top of head; in addition to nuptial tubercles, there is an elongate fleshy or spongy pad extending in a narrow band from nape to dorsal fin origin, wide anteriorly, the pad narrows to engulf first dorsal ray.

Colour Overall colouration usually dark. Dark olive-green or brown above, with silvery or brassy reflections on sides and silvery white below, but in parts of western Canada they may be quite light in colour. Young and nonbreeding adults lighter in colour but exhibiting a distinct lateral band which extends from caudal peduncle to head. The band may be absent on breeding males or, if present, it becomes very diffuse anteriorly. The band is usually most apparent on preserved specimens. Dymond (1926) described the saddle-like pattern often associated with the fathead in which a light area develops just behind the head and another beneath the dorsal fin, the areas between producing a saddle effect. McPhail and Lindsey (1970) noted that they had not observed this, nor indeed have we, but it is described by Dymond (1926), Trautman (1957), Cross (1967), and others.

In eastern Canada, at least, breeding males are very dark, including even the fins, particularly the dorsal fin. The tubercles on the head are light in colour and the rugose, spongy pad on the back is slate-blue or gray.



Systematic notes The fathead minnow varies greatly in many characters throughout its wide geographic range and some populations have been designated as subspecifically distinct; e.g., *Pimephales promelas promelas*, the northern fathead minnow; *P. p. harveyensis*, Harvey Lake fathead minnow; and *P. p. confertus*, southern fathead minnow (Hubbs and Lagler 1949, 1958). The pattern of variation, however, caused some workers to doubt the validity (Taylor 1954). A statistical analysis of geographic variation was published by Vandermeer (1966), whose work suggested that two of the three described subspecies intergrade clinally. He, like Taylor, recommended that subspecies not be recognized. Vandermeer found that eye diameter showed a north–south trend, the northern fish having smaller eyes; another character studied was completeness of lateral line, which showed a northeast–southwest cline, with northern fish having the least complete lateral line. However, since some Canadian populations exhibit a nearly complete lateral line, the subject obviously warrants further study.

Distribution The fathead minnow ranges through most of central North America, from Louisiana and Chihuahua, Mexico, north to the Great Slave Lake drainage; and from New Brunswick on the east to Alberta on the west.

In Canada, it occurs from the Saint John River drainage near Edmundston, N.B., west through southern Quebec; all of Ontario; north in Manitoba to Lake Athapapuskow and God's Lake; north in Saskatchewan to parts of the Churchill River drainage; through all of Alberta north into the Northwest Territories to the Hole Lakes, Little Buffalo River, which flows north into Great Slave Lake. There are no records for British Columbia.

Biology The spawning behaviour and activities of the fathead minnow in spring are rather well known because of the early interest in raising this fish in ponds for feeding pond-reared black bass. The breeding habits are generally very similar to those of the bluntnose minnow, *P. notatus*. Observations on populations in Quebec lakes were reported by Wynne-Edwards (1932) and Richardson (1937). Spawning activities commence when water temperatures reach 60° F (15.6° C), although 64° F (17.8° C) was considered minimum spawning temperature by Dobie et al. (1956). Spawning is prolonged and may continue into August in many parts of the range. Dymond (1926) reported ripe females and males from the vicinity of Lake Nipigon, Ont., June 17, 1924; Toner (1943) found a male guarding eggs attached to the underside of a rock embedded in a bank of Jones Creek, St. Lawrence River drainage, June 12, 1936; Richardson (1937) observed spawning activities in Quebec, June 19, 1933.

The male selects for a spawning site the underside of a log or branch, large rock, board, or, more rarely, a lily pad, in shallow water, 2–3 feet deep (Wynne-Edwards 1932). A female is sought out and herded into position below the nesting site, the male usually positions himself on the female's left side. After much circling below the nesting site, the female is nudged and lifted by the male's back until she lies on her side immediately below the undersurface of log or branch. The adhesive eggs are deposited, fertilized by the male, and the female driven off. The female has an ovipositor (Flickinger 1969), which is doubtless an adaptation to this unusual method of egg deposition. After deposition of the eggs, the male is most aggressive and will drive off all other intruding small fishes, aided, of course, by the large tubercles on the snout. Males may seek out a number of females in a like manner, so that each nest contains eggs from more than one female and these in various stages of development, and, of course, each female deposits eggs in more than one nest.

In addition to guarding the nest, Wynne-Edwards reported that the eggs were stroked or rolled by the male, using the thick rugose pad on his back, but subsequent authors (Markus 1934; Hubbs and Cooper 1936) cast doubt on this function of the male.

Wynne-Edwards reported the eggs to be 1.3 mm in diameter (Quebec) and Markus 1.15 mm (Iowa). The time to hatching depends on temperature but on the average requires 4.5–6 days; at 77° F (25° C) 5 days are required. Newly hatched young are about 5 mm long, and white in colour. Fish (1932) described and illustrated a young fathead at the 11.6 mm stage. The pattern of scale formation was described by Andrews (1970) who noted that in Colorado no scales were found on fish smaller than 14 mm and average length for first scale formation was 16.3 mm.

Growth is rapid in warm, food-rich waters, so rapid that Markus considered that fish hatched in May in Iowa reached adult size and were spawning by late July, but, as Hubbs and Cooper noted, such rapid growth is unlikely in more northerly waters. In Canada, adult sizes of 2.0–2.8 inches (50–70 mm) total length are probably not attained until at least age 2. Maximum total lengths from museum collections, in millimeters (Quebec 88, Ontario 94, Manitoba 83), suggest greater ages than reported elsewhere, but rates of growth studies have apparently not been calculated for Canadian populations.

In all populations the males grow more rapidly and to a larger size than females. This is characteristic of species of minnows, such as the bluntnose minnow, in which the males guard the nest, whereas the female is usually larger where no nest-guarding occurs.

Most reports indicate that the fathead is quite short lived, rarely living beyond age 2. Markus (1934) reported 80% mortality of the adult fish after spawning, and it appears that this postspawning mortality is a characteristic of the species, although it has not been reported for Canadian populations. In a critical age and growth study in Iowa, Carlson (1967) reported one fish of age 3, and noted that annulus formation coincided with peak spawning, which took place in July. Whether these circumstances apply to Canadian populations is not known but it seems probable that more fathead would reach age 3 in our cooler waters.

The preferred habitats and species associated with the fathead minnow seem to vary greatly throughout the Canadian range. In general, it prefers the still waters of ponds to the flowing waters of streams. In the St. Lawrence drainage, it often occurs in muddy ditches and warm brooks. In north-central Ontario it occurs most frequently in clear but stained, acid waters of beaver ponds and small lakes, usually in association with fivespine sticklebacks, pearl dace, and finescale dace (Dymond 1926; Dymond and Scott 1941). In the Prairie Provinces it occurs in reservoirs, muddy brooks, and alkaline lakes, sometimes in considerable numbers. In a review of the saline lakes in Saskatchewan, Rawson and Moore (1944) noted that the fathead minnow was one of the more abundant species in such lakes and could tolerate salinities in excess of 10,000 ppm. McPhail and Lindsey (1970) reported it in muddy streams and mud-bottomed lakes in the northwest.

Food of the fathead seems not to have received critical attention; most authors refer to the studies of Coyle (1930) who found algae to be one of its main foods in Ohio. Elsewhere in the United States the items found in stomachs include organic detritus, bottom mud, aquatic insect larvae, and zooplankton. The elongate intestine is characteristic of cyprinids that have a high vegetative content in their diet.

The fathead minnow is an ideal forage fish since it is widely distributed, small, highly prolific, and has a prolonged spawning period, assuring the availability of recently hatched or small fatheads to predators throughout the warm summer months. To list all predators of this minnow would require listing all fish-eating birds and fishes associated with it.

Bangham and Venard (1946) examined 60 specimens of fathead minnows from lakes in Algonquin Park, Ont., and found 46 parasitized. Forty-three from Chickaree Lake were infected with the trematode *Posthodiplostomum minimum*. They noted that northern dace and redbelly dace caught in the same location were only lightly infected with this trematode.

Bangham and Hunter (1939) examined 11 specimens from Lake Erie, Ont. Four fish were infected, the parasites identified being trematodes, *Neascus* sp., Protozoa, and Myxosporidia.

Ligula intestinalis was found in 88% of a sample of 290 fish examined in Nebraska by McCarraher and Thomas (1968). The number of parasites per infected minnow ranged from 1 to 22. The lake in question, Rodgers Lake, was highly alkaline with a *p*H of 9.2, which is perhaps significant.

Hoffman (1967) listed species of Protozoa (2), Trematoda (10), Cestoda (5), Nematoda (2), and Crustacea (1), from this fish in North American waters.

Relation to man The fathead minnow has attracted much attention as a forage fish suitable for pond culture in the United States; often as food for pond-reared smallmouth bass and other game fish. Considerable information on pond cultural practices and yields are available in Dobie et al. (1956) who reported yields up to 328 pounds (200,000 fish) per acre. Pond culture has not been practiced seriously in Canada as yet, although when it is, the fathead will no doubt offer promise.

It is not generally regarded as an important bait species in Canada because of its small size, but in certain areas where it is abundant, such as in the Kenora region of Ontario, it may be a valuable bait fish.

Its primary importance in our waters at present is as a forage fish, converting algae, organic detritus from bottom deposits, and planktonic organisms into food for other fishes. Its value in this role is inestimable.

Nomenclature

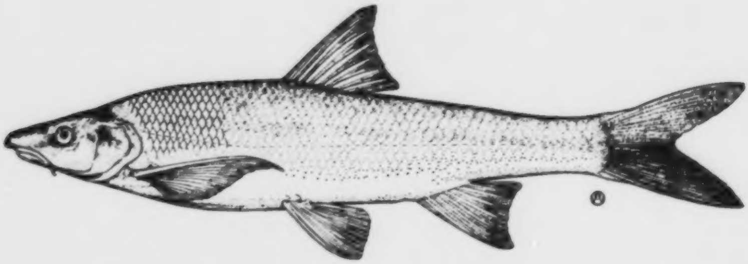
Pimephales promelas — Rafinesque 1820c: 53 (type locality near Lexington, Ky.)
Pimephales milesi Cope — Jordan and Evermann 1896–1900: 217

Etymology *Pimephales* — fat; head; *promelas* — before; black.

Common names Fathead minnow, northern fathead minnow, blackhead minnow. French common name: *tête-de-boule*.

FLATHEAD CHUB

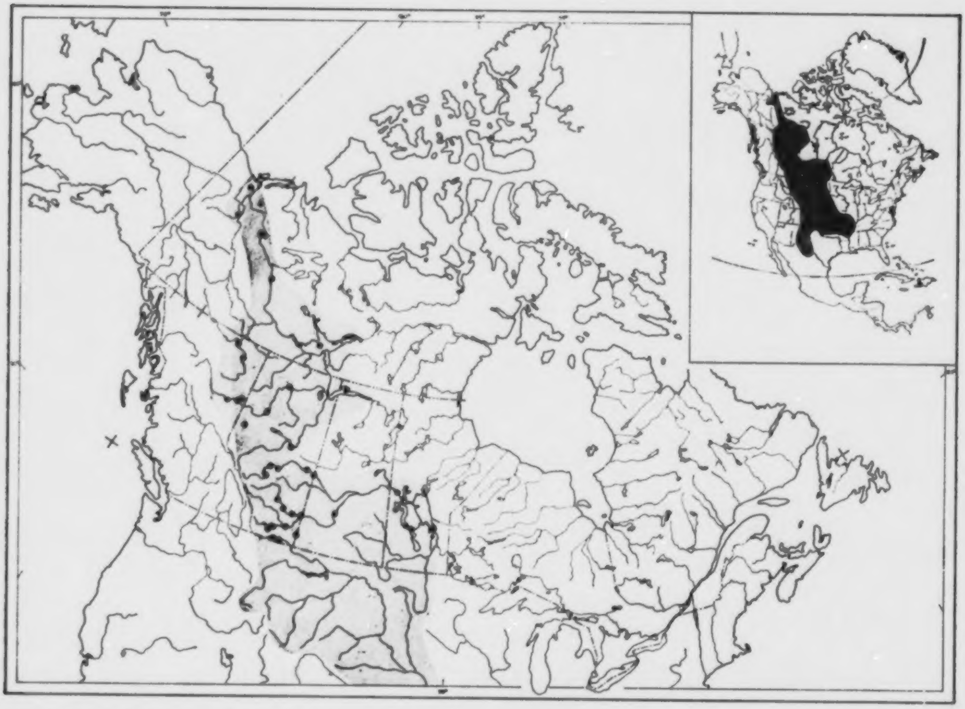
Platygobio gracilis (Richardson)



Description Body elongate, about 5–7 inches (127–178 mm) average total length, not strongly compressed laterally, caudal peduncle deep, about one-half body depth, body depth 14.5–20.0% of total length. Head small, wedge-shaped, dorsal surface distinctly flattened, length 16.8–18.9% of total length; eye relatively small, its diameter 13.6–23.8% of head length; snout long, protruding beyond upper jaw, nostril flaps conspicuous, length 35.8–41.3% of head length; interorbital region distinctly flattened, wide, width 38.0–52.4% of head length; mouth large, subterminal, overhung by snout, extending posteriorly to about midpoint of eye; well-developed terminal barbels at end of maxilliaries; pharyngeal teeth 2,4–4,2. Fins clear: dorsal 1, its origin usually slightly in advance of origin of pelvic fins, base short but fin high, pointed, trailing edge falcate, rays 8, rarely 7; caudal distinctly forked, lobes pointed, lower lobe darker than upper lobe; anal 1, its origin at a point below tip of depressed dorsal, trailing edge distinctly falcate, rays usually 8, rarely 7 (McPhail and Lindsey 1970, said 8 or 9); pelvics originate usually under dorsal fin origin, pelvic axillary process evident, rays usually 8, rarely 7 or 9; pectorals long and acutely pointed, extending at times almost to pelvic origins especially in males but variable, rays 16–19, usually 17 or 18. Scales cycloid, large, persistent; lateral line complete, slightly decurved, scales 50–58 (McPhail and Lindsey said 42–59). Peritoneum silvery; intestine short. Vertebrae 40–47, usually 43–47 in Canadian waters.

Nuptial tubercles minute, on top of head and sparsely on scales of back, also on dorsal surface of first pectoral and pelvic rays and on lateral faces of first dorsal fin ray.

Colour Brownish or dusky above, silvery on sides and light below; pigmentation ceases abruptly midlaterally, coincidentally



with lateral line posteriorly, but anteriorly the lateral line curves downward below the line of pigmentation.

Fins clear except lower lobe of caudal fin, which is darker than upper lobe.

Systematic notes We have chosen to use the generic name *Platygobio* instead of *Hybopsis* for the same reasons expressed by McPhail and Lindsey (1970). It seems unnecessary to repeat them here.

The flathead chub exhibits considerable morphological variation throughout its North American range. This geographic variation was studied in detail by Olund and Cross (1961) who concluded that observed differences were best expressed by the recognition of subspecies, *Platygobio gracilis gracilis*, the northern flathead chub, which occurs in Canada and parts of the United States; and *P. g. gulonella*, the southern flathead chub, which occupies the western and southern part of the range. The populations in Frenchman River, in the Cypress Hills region of southwestern Saskatchewan, were considered by these authors to be intergrades between the two subspecies. *Platygobio g. gracilis* attains a larger size, has a slender, streamlined body, a wedge-shaped, flattened head, falcate fins, and a larger number of scales, pectoral fin rays, and vertebrae. Bailey and Allum (1962) interpreted the data differently, and considered the differences exhibited throughout the range as manifestations of environmental differences rather than genetic ones. The problem obviously requires further study.

Distribution The flathead chub occurs in west central North America, from 35° to 68°N latitude; from the Mississippi River and tributaries at about the South Canadian River in Oklahoma to the Rio Grande in New Mexico, north to Lake Winnipeg, and the Saskatchewan and Mackenzie River systems.

In Canada, it occurs in Manitoba, where it is occasionally caught in commercial fishermen's nets in Lake Winnipeg. It is said to be common around rapids in the Assiniboine

River, and Keleher and Kooyman (1957) reported it from Kelsey Lake, 53°37′N, 101°00′W. In Saskatchewan, it occurs in the Cypress Hills area, the South and North Saskatchewan rivers, and Lake Athabasca. In Alberta, it occurs throughout the province, from the Milk River to North and South Saskatchewan rivers and the Red Deer and Peace River systems. In British Columbia, it is present in the northeastern part, in the Peace River and at Lynx Creek east of Hudson Hope, and in the Fort Nelson and Muskwa rivers (Carl et al. 1967). In the Northwest Territories it occurs from Great Slave Lake through the Mackenzie River to the delta.

Biology Details of the spawning habits of the flathead chub are unknown but available information indicates that spawning takes place in summer. Olund and Cross (1961) favoured mid or late summer: they reported collections of males and females in spawning condition, taken in the Milk River, in August 1955; prespawning females caught in the Saskatchewan River in Saskatchewan, on June 7, 1957; and a single prespawning female from the Red Deer River in June, 1952. McPhail and Lindsey (1970) reported the capture of females with large ovaries of almost free eggs, and one spent female caught in the Mackenzie River at 64°N, on June 27. They considered that spawning had ceased before August 4 in the Peace River at Fort Vermilion since the females caught on that date were spent. Olund and Cross suggested that spawning occurred when water levels receded to the seasonal low, i.e., summer in Canada.

No growth studies have been published, especially for Canadian populations, but McPhail and Lindsey (1970) suggested that this chub lives for several years, since several size groups may be present in a single collection. The largest specimen known to them was one 12.5 inches (317 mm) total length from the Peel River at 66°N. A female chub in the Royal Ontario Museum collection measured 11.4 inches (290 mm) and is also from the Peel River, 15 miles from Aklavik, 68°N. Olund and Cross suggested that sexual maturity was attained at about 3.3 inches (85 mm) standard length.

The flathead chub occurs in the turbid, flowing waters in main channels of large rivers throughout its range, sometimes moving into smaller streams in the spawning season (Olund and Cross 1961). It is well designed for life in such an environment, as its elongate body, pointed snout, and elongate fins attest. It is seldom found in the clear, still waters of ponds or lakes.

The flathead chub is predaceous and feeds on a wide variety of organisms, probably both by sight and also by using the gustatory or taste-buds associated with the barbels. Insects, adults especially, form a major part of the diet, according to data compiled by Olund and Cross, who included information from Saskatchewan and Alberta. Water boatmen (Corixidae) made up 35% of the stomach contents of the Saskatchewan sample, and such terrestrial insects as ants (21%), beetles (30%), and dipterous flies (9%) were important in Alberta.

McPhail and Lindsey (1970) also noticed the importance of terrestrial and aquatic insects but observed, in addition, that small fishes and even young rodents have been found in the stomachs.

Severe infections of the tapeworm (*Proteocephalus*) in young flathead chubs were reported by Hubbs (1927). The heavy degree of parasitism apparently produced abnormalities that resulted from the retention of juvenile characters, and ultimately caused the death of the chubs before reaching maturity. Hoffman (1967) listed only the larval form of the trematode *Bolbophorus confusus* from this species in North American waters.

Relation to man The flathead chub is not of great economic importance in Canada, but it does afford some sport when angled with a small baited hook or artificial fly. It is also occasionally used as a food fish. Carl et al. (1967) noted that the Indians at Fort Nelson, B.C., made a sort of stew from these fish, which they caught by baited hook. In Iowa, it is a preferred bait fish for blue catfish because of its size and hardiness.

Nomenclature

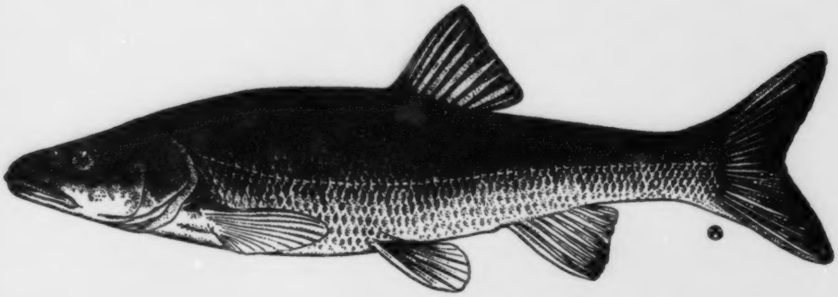
Cyprinus (*Leuciscus*) *gracilis* — Richardson 1836: 120 (type locality Saskatchewan River at Carleton House)
Platygobio gracilis (Richardson) — Jordan and Evermann 1896–1900: 326
Pogonichthys communis Girard — Jordan and Evermann 1896–1900: 326
Coregonus angusticeps Cuvier and Valenciennes — Jordan, Evermann, and Clark 1930: 136
Hybopsis gracilis — Bailey 1956: 356

Etymology *Platygobio* — flat; gudgeon; *gracilis* — slender.

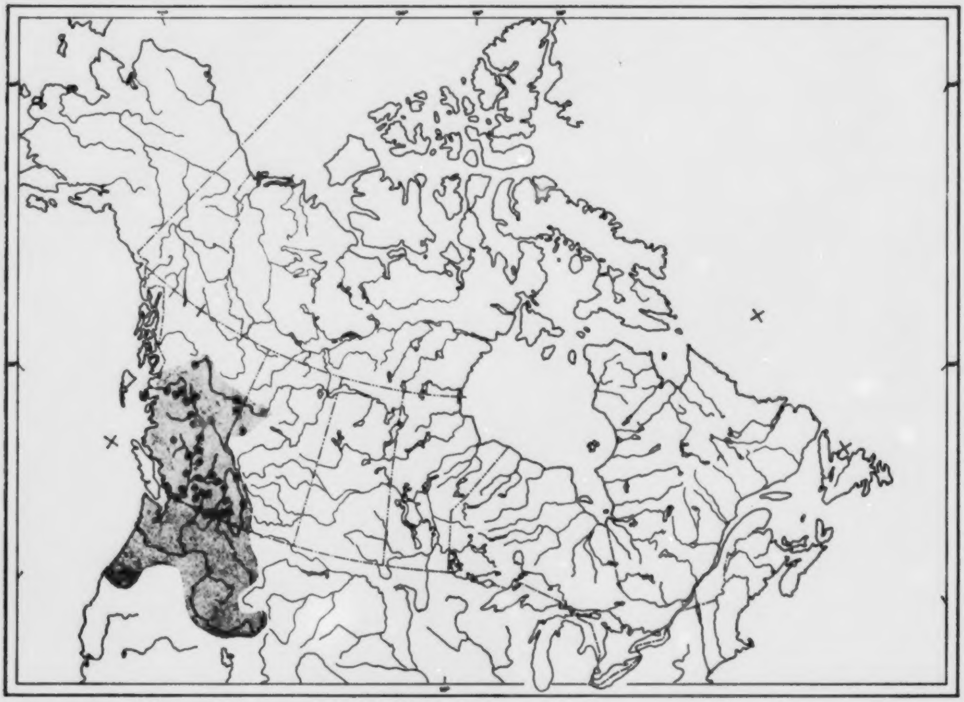
Common names Flathead chub, Saskatchewan dace. French common name: *méné à tête plate.*

NORTHERN SQUAWFISH

Ptychocheilus oregonensis (Richardson)



Description Body elongate, size large (maturing at 12 inches (305 mm) total length), somewhat compressed laterally, not deep bodied, greatest depth 14.7–18.5% of total length, belly gently rounded in mature individuals. Head moderately long, its length 22.3–23.3% of total length; eye small in adults, 16.2–19.1% of head length; but larger in young 3 inches (76 mm) long, when 23.7–26.7% of head length; snout long, 31.6–34.6% of head length of adults; interorbital width 26.9–32.2% of head length; mouth terminal, large, extending back to below anterior margin of eye; pharyngeal teeth tips hooked, usually 2,5–4,2 (Dymond 1936, stated outer row sometimes 3 instead of 2, inner sometimes 4–4). Fins: all fins clear; dorsal 1, its origin over, or slightly behind, origin of pelvic fins, dorsal rays 9, sometimes 10; caudal distinctly forked, lobes pointed; anal 1, its origin below free edge of dorsal fin, rays 8, seldom 9 (McPhail and Lindsey 1970, gave 8–10); pelvics small, origin under or slightly in advance of dorsal fin origin, rays 9;



pelvic axillary process usually a ridge; pectorals relatively short, rays 15 or 16; McPhail and Lindsey (1970) gave 15–18 (usually 16) for northern populations. Scales cycloid, small, 65–77 in lateral line; lateral line complete. Peritoneum speckled; intestine short. (*See* Weisel 1962, for a thorough description of digestive tract.) Vertebrae 44(2), 45(7), or 46(7); McPhail and Lindsey (1970) reported 40–43 but must exclude 4 Weberian vertebrae.

Nuptial tubercles fine, on head and back, and on the pectoral and pelvic fins and sometimes on caudal fin.

Colour Dark green or green-brown above, lighter on sides and silvery white or cream ventrally. The males are colourful at spawning time when the lower fins become yellow or yellow-orange. Young fish, when preserved, exhibit a black spot at the base of the caudal fin and a rather weak, narrow, lateral band that commences before the dorsal origin and terminates almost at the caudal spot.

Systematic notes *Ptychocheilus oregonensis* is a stable species in itself but there are three additional members of the genus *Ptychocheilus*, which occur in other west coast watersheds — *P. grandis*, the Sacramento squawfish; *P. lucius*, Colorado squawfish; and *P. umpquae*, the Umpqua squawfish.

Distribution The northern squawfish occurs on the Pacific slope of western North America, in the Malheur Lake system of Oregon, in the Columbia River system and north in the Pacific slope drainages to the Nass River of British Columbia. It occurs east of the Continental Divide only in the Peace River system.

In Canada, it occurs in British Columbia, through the entire Fraser, Columbia, and Skeena River systems, through the Klinaklini and Dean River systems and in Meziadin

Lake and the settlement of Aiyansh of the Nass River system. It has traversed the Continental Divide in the Peace River system and occurs in Summit and McLeod lakes, east in the Peace River to the Peace River townsite in Alberta.

Biology Squawfish spawn from late May to July (Carl et al. 1967). Spawning takes place in gravelly shallows, sometimes along a lake shore, sometimes in lakes near a tributary stream, and sometimes a short distance upstream. Observations by Jeppson and Platts (1959) and Patten and Rodman (1969) suggested lake-dwelling forms spawned in streams only when suitable gravelly shallows in lakes were not available. The spawning fish tend to gather in large numbers, but no nest is built. A female may be accompanied by a few to many males, the small eggs and sperm are released close to the bottom, and the eggs, which are adhesive and demersal, and 1 mm in diameter, settle in the gravel. Some authors (Carl et al. 1967) described the eggs as greenish, others (Patten and Rodman 1969) observed them to be pale orange. Each female is said to carry large numbers of eggs and probably does not release all of its eggs at one time.

According to Carl et al. (1967), the eggs hatch in about 1 week. Sexual maturity is attained in about 6 years when the squawfish are about 12 inches (305 mm) long. The following fork lengths (mm) at successive ages are calculated figures from British Columbia populations at Okanagan Lake and Woods Lake (Clemens 1939):

Age	Okanagan L.	Woods L.
1	46	48
2	89	99
3	130	147
4	160	198
5	201	226
6	239	274
7	–	302
8	–	345
9	–	366
10	–	386
11	–	411

A maximum weight of 29 pounds (13 kg) (no length available), and a length of 25 inches (360 mm), were reported by McPhail and Lindsey (1970) who also suggested life expectancy of 15–20 years.

The northern squawfish is typically a lake species, preferring still waters to swift streams. The young inhabit inshore waters in summer months, moving offshore into deeper waters in fall; the larger fish tend to remain offshore.

The food habits of the squawfish have received considerable attention. Ricker (1941) examined over 300 stomachs and concluded that while in inshore waters in spring and summer, these fish consume shiners (*Richardsonius balteatus*), sticklebacks, terrestrial insects, and some plankton. Aquatic insect larvae and crustaceans may also be eaten at this time. During fall and winter, squawfish move offshore into deeper water where fish become the major food item.

Young squawfish, 1–4 inches (25–102 mm), feed heavily on insects but as they grow larger, fish become increasingly important, and very large squawfish feed almost exclusively on other fishes and, sometimes, crayfishes.

Male squawfish were observed eating eggs on their own spawning ground by Patten and Rodman (1969), who also noted that squawfish eggs were eaten by prickly sculpins and newts.

Bangham and Adams (1954) examined 408 specimens of northern squawfish from 32 locations in British Columbia and found 373 parasitized. They reported many different species of parasites and noted that there were often very heavy infections of encysted eye flukes, *Diplostomulum* sp., and the strigeid fluke *Posthodiplostomum minimum* (*see* Bangham and Adams (1954), for further details).

Hoffman (1967) listed trematodes (5), cestodes (3), nematodes (5), acanthocephalans (1), leeches (1), crustaceans (2), and molluscs (1) as parasitic on squawfish.

Relation to man Any North American fish species that is predatory and grows to a size in excess of 5 pounds, will be of interest to man, either directly as a sport or game fish, or indirectly as a competitor with man for more desirable species. The squawfish qualifies, in a minor way, as a sport fish, for it feeds at the surface in the evening and will take a fly. Its relatively large size ensures at least a short-lived tussle, but it quickly succumbs to the angler.

It is in the role of a competitor, that it is better known since, being large and predatory, it consumes other fishes, and when salmon (*Oncorhynchus spp.*), especially sockeye salmon, are included in its diet, the squawfish is in conflict with the most effective and selfish predator of all. In addition and perhaps equally important, it often competes with salmon and trout for the same food supply.

Proof of man's interest in the squawfish becomes readily apparent from the titles of some scientific papers, such as *Ecology and control of Columbia squawfish*; *A chemical selectively lethal to squawfish*; *The control of squawfish by use of dynamite, spot treatment, and reduction of lake levels.*

Squawfish do eat the young of salmon and trout, commencing when they are only 4 inches (102 mm) long, in the case of sockeye. Ricker (1941), considered the predation to be most serious from September to April. For further information, *see* papers by Foerster and Ricker (1942), Jeppson (1957), Jeppson and Platts (1959), and Ricker (1938a, 1941).

The squawfish is not unanimously regarded as a good food fish, although the flesh is edible. Rostlund (1952) suggested that Indian peoples were not enthusiastic about its food qualities although Jordan and Evermann (1908) wrote that it ". . . is highly esteemed by the Indians, hence its most popular name."

Nomenclature

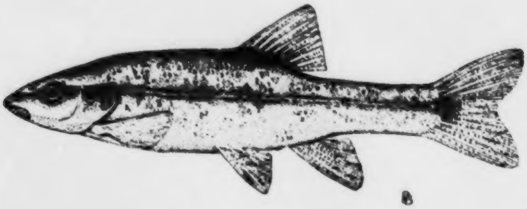
Cyprinus (*Leuciscus*) *Oregonensis* (Richardson) — Richardson 1836: 305 (type locality Columbia River)
Leuciscus oregonensis (used by Günther 1868) — Evermann and Goldsborough 1907a: 95
Ptychocheilus oregonensis Richardson — Halkett 1913: 62
Ptychocheilus oregonensis (Richardson) — Dymond 1936: L68
Ptychocheilus oregonense (Richardson) — Lindsey 1956: 768

Etymology *Ptychocheilus* — fold; lip, the skin of the mouth behind the jaws being folded; *oregonensis* — of Oregon.

Common names Northern squawfish, Columbia squawfish, Columbia River dace. French common name: *sauvagesse du nord.*

BLACKNOSE DACE

Rhinichthys atratulus (Hermann)



Description Body stout, elongate, average length about 2.5 inches (64 mm), spindle-shaped, not strongly compressed laterally, body depth 15.1–22.9% of total length. Head triangular, broad, its length 19.6–23.2% of total length; eye relatively small, its diameter 16.6–28.5% of head length; snout long, upper lip overhanging mouth, snout length 32.0–41.6% of head length; interorbital broad, 33.3–46.1% of head length; mouth slightly inferior, nonprotractile, gape terminating below nostril, a small barbel visible at each corner of the mouth; pharyngeal teeth 2,4–4,2. Fins: dorsal 1, its origin slightly posterior to pelvic fin origin, rays usually 8(54), occasionally 7(3); caudal shallowly forked, lobes rounded; anal 1, its origin approximately below insertion of dorsal fin, rays usually 7(55), rarely 6(1), or 8(1); pelvics relatively small, origin slightly in advance of dorsal fin origin, rays 8(38); pectorals relatively small, rounded, rays 13–15 east of Ontario, 14–16 in Ontario and Manitoba. Scales cycloid, small, 56–68 in lateral line, radii in all fields; they commence to form at 15 mm and nearly cover body by 20 mm (Noble 1965); lateral line straight or nearly so, complete. Peritoneum uniform brown; swim bladder well developed in adults. Vertebrae 37–40, usually 38 or 39.

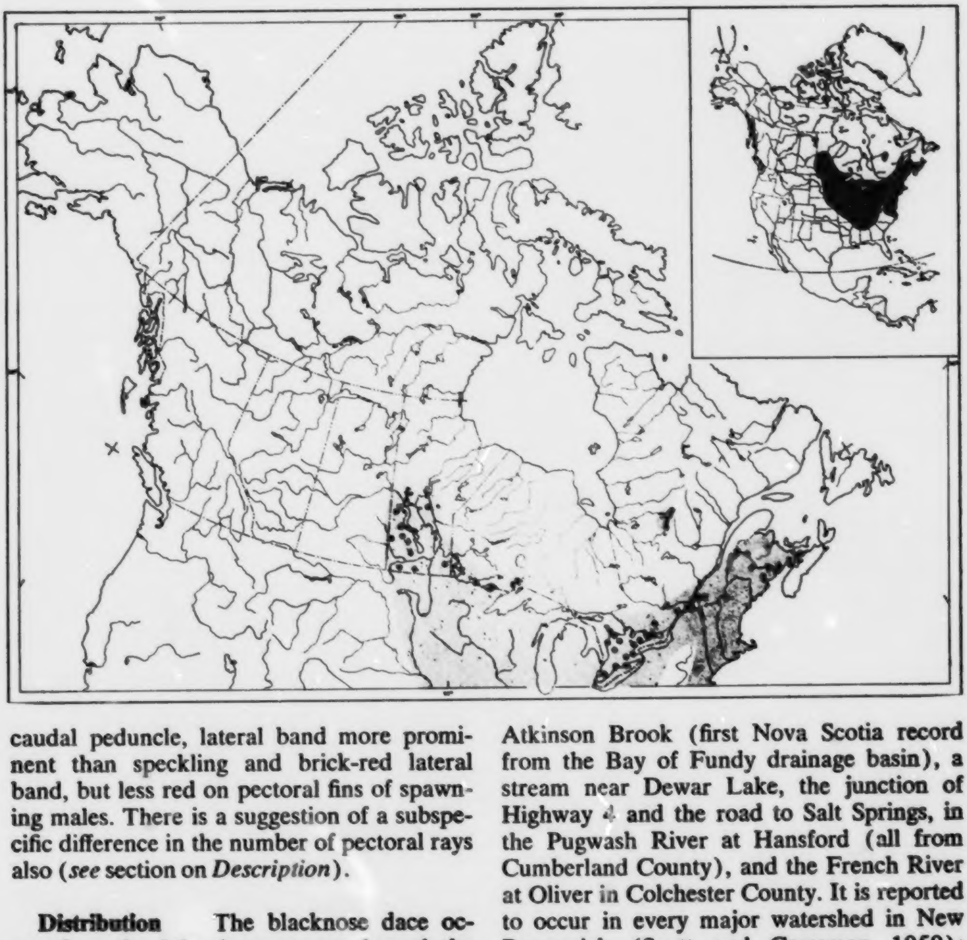
Nuptial tubercles developed on breeding males, on head, over entire body surface, and on fins; tubercles on pelvic fins better developed than on other fins.

Colour Overall colouration is dark with speckles or mottling on sides. The back is olive-green to dark brown, and the sides are sprinkled with specialized, darkened scales becoming lighter on lower sides and silvery white below.

Breeding males have a rust-red colouration on the sides and, some orange or red colouration on the pectoral fins, the intensity depending on the subspecies; *R. a. meleagris* perhaps more brilliantly coloured, but *see* section on *Systematic notes.*

Systematic notes *Rhinichthys atratulus* (Hermann) is generally considered to be represented throughout its range by at least four subspecies. Two of these are southern in distribution and do not enter our area but the remaining two have Canadian distributions as follows: *R. a. atratulus* (Hermann), eastern blacknose dace, ranges from eastern Lake Ontario, east through southern Quebec, into New Brunswick and Nova Scotia; *Rhinichthys a. meleagris* Agassiz, western blacknose dace, west from eastern Lake Ontario through the Great Lakes and Lake of the Woods to Manitoba.

Rhinichthys a. atratulus is considered to have a more slender caudal peduncle, dark speckling more prominent than lateral band, and spawning males with orange-red pectoral fins and a cinnamon-brown to orange lateral band, whereas *R. a. meleagris* has a deeper



caudal peduncle, lateral band more prominent than speckling and brick-red lateral band, but less red on pectoral fins of spawning males. There is a suggestion of a subspecific difference in the number of pectoral rays also (*see* section on *Description*).

Distribution The blacknose dace occurs from the Atlantic coast west through the Great Lakes region to North and South Dakota. Southward it is found on both sides of the Appalachian Mountains to Georgia, Alabama, and Mississippi (Moore 1968).

In Canada, the species inhabits cool, clear streams from Nova Scotia to Manitoba. McKenzie (1959) remarked that it may be taken, occasionally, in brackish water in Miramichi River tributaries before the head of tide. In Nova Scotia it was reported by Livingstone (1953) from only two localities in Cumberland County — River Philip, and a branch of the Shinimicas River that flows into Northumberland Strait. Cook (1961) extended the range to five new localities — Atkinson Brook (first Nova Scotia record from the Bay of Fundy drainage basin), a stream near Dewar Lake, the junction of Highway 4 and the road to Salt Springs, in the Pugwash River at Hansford (all from Cumberland County), and the French River at Oliver in Colchester County. It is reported to occur in every major watershed in New Brunswick (Scott and Crossman 1959); widespread in Quebec in the St. Lawrence River drainage; and ranging east to Gaspé; through southern Ontario to Lake of the Woods (not recorded north of Sault Ste. Marie); and in Manitoba, where it reaches its northernmost and westernmost limits of range in Canada, it has been recorded from Pembina, Whitemud, and Assiniboine River systems, and in tributary streams of lakes Dauphin, Winnipegosis, and Swan. These localities are in western Manitoba and Keleher and Kooyman (1957) noted that it had not been collected east of La Rivière (98°43′W long) except in the southern part of the province.

Biology Blacknose dace spawn in spring, when water temperatures reach about 70° F (21.1° C), usually in May or June. Spawning takes place over gravel bottoms in the fast water of shallow riffles, where the water is a few inches to a foot deep. Raney (1940c) first drew attention to the differences in the spawning habits of two races of blacknose dace, *R. a. atratulus* and *R. a. meleagris*, from studies in New York State waters. Additional differences in spawning behaviour apply to the southern subspecies as well. No nest is built, although a territory may be established, particularly by male *meleagris* (which, logically, has the better-developed tubercles) but may be abandoned once spawning begins in earnest, although a large male will tend to remain in his territory and by successive spawning will wear a depression near the centre. Clearing away of silt may be performed by *atratulus* but silt clearing by *meleagris* may be effected, perhaps incidentally, as Raney noted, by the lower fins during ceaseless guarding of territory. At the height of spawning, one to several males will accompany and harass every female appearing on the spawning ground. The spawning male and female orient side by side, the tubercles on the male probably helping him to retain contact with the female; the eggs and sperm are extruded during violent vibrations, which may last up to 2 seconds. The female has a well-developed anal papilla that serves as an ovipositor and some eggs may be forced into the sand or gravel during the spawning act. Raney observed that there was a rush by other dace to eat the eggs, which are vigorously defended by the male.

Traver (1929) noted that the eggs are 0.8 mm in diameter, transparent, and amber in colour. Newly hatched fry are about 5 mm long. Time to hatching has apparently not been recorded. Fish (1932) figured and described a 17.25-mm specimen from a Lake Erie tributary.

The age of blacknose dace can be determined from scales and were used by Noble (1965) for an Iowa population of *R. a. meleagris*. No growth studies have been made for Canadian populations but Trautman (1957) reported lengths of 25–61 mm for 1-year-old Ohio dace. Hubbs and Cooper (1936) considered that Michigan populations matured at age 2. It is probable that the species is short lived, reaching an age of 3, or at most, 4 years.

The blacknose dace prefers small, clear, swiftly flowing streams with gravelly substrate. Trautman (1957) demonstrated the importance of gradient by noting that the areas originally occupied in Ohio were those having a maximum relief of over 100 feet.

The food of the blacknose dace consists primarily of aquatic insect larvae, according to studies conducted in Iowa by Noble (1965), who noted that chironomids were the most important food but that diatoms and desmids were eaten during November and March. Noble did not detect any change in diet with increase in size or age.

Blacknose dace prey on their own eggs during spawning (Raney 1940c). The young and adults serve as food for large brook trout. Since this dace is often the most common fish species in the streams in the Maritime Provinces, it is preyed upon by many fish-eating birds, such as the American merganser (White 1957).

Houde (1964) reported the larval strigeid trematode *Crassiphiala bulboglossa*, which causes black-spot, in the blacknose dace from Mill River, Williamsburg, Mass., the first report of this trematode as a causative agent for black-spot in the blacknose dace.

Wagner (1969) collected blacknose dace, from a highly localized site in a limestone creek in central Pennsylvania, with the leeches *Illinobdella alba* and *I. moorei* attached to the fins.

Bangham and Hunter (1939) examined 54 specimens of blacknose dace in Lake Erie and reported 27 from the east end of the lake parasitized with trematodes, *Neascus vancleavei* and *N. rhinichthysi*.

Hoffman (1967) noted this species infested with several protozoans, trematodes, nematodes, and the larval form of a cestode, *Proteocephalus* sp.

Relation to man The blacknose dace is used to a limited extent as a bait minnow in Ontario and Quebec. It is one of the more common minnows in the fast-flowing streams in the southern portion of eastern Canada; many of these are trout streams and in such situations it may serve as an important food of large brook trout. However, it is strictly a stream species and is not important in lakes.

It is considered to be a relatively hardy species in the United States, where it is popular as a bait fish for bass and catfish in Iowa and other states, such as Ohio and Minnesota. Dobie et al. (1956) noted that artificial fertilization is practical.

Nomenclature

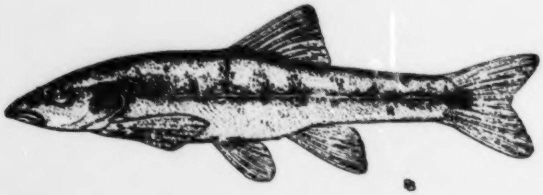
Cyprinus atratulus. Nobis.	— Hermann 1804: 320 (type locality America septentrionali)
Cyprinus atronasus	— Mitchill 1815a: 460
Leuciscus atronasus	— Perley 1852: 194
Rhinichthys atronasus (Mitchill)	— Evermann and Goldsborough 1907a: 97
Rhinichthys atratulus (Hermann)	— Hubbs 1936: 124

Etymology *Rhinichthys* — snout; fish — the snout being prominent; *atratulus* — probably from *atratus*, meaning clothed in black as for mourning.

Common names Blacknose dace, black-nose dace, eastern blacknose dace, dace, striped or redfin dace, brook minnow, potbelly, pottlebelly. French common name: *naseux noir*.

LONGNOSE DACE

Rhinichthys cataractae (Valenciennes)



Description Body stout, averaging about 3 inches (76 mm) total length, nearly round in cross section, especially anteriorly between head and dorsal fin, body depth 14.8–19.4% of total length. Head triangular, broad, usually a slight but distinct hump at nape, head length 19.4–25.0% of total length; eye relatively small, its diameter 16.6–24.1% of head length; snout long, extending beyond, and overhanging mouth, bulbous, its length 38.4–50.0% of head length; interorbital broad, its width 26.0–42.4% of head length; mouth inferior, nonprotractile, overhung by snout, upper lip fleshy, gape terminating in front of eye, a small barbel at each corner of mouth, hidden in skin fold, conspicuous on large adults; pharyngeal teeth usually 2,4–4,2, occasionally 1,4–4,1 or 1,4–4,0, but always 4 in main row. Fins: dorsal 1, its origin posterior to pelvic fin origin, rays 8(58); caudal shallowly forked, lobes rounded; anal 1, origin approximately below insertion of dorsal fin, rays 7(58); pelvics small, origin in advance of dorsal origin, pelvic axillary process present, rays usually 8(44), rarely 7(2) (McPhail and Lindsey 1970, said sometimes 9); pectorals short, rounded and somewhat paddle-like, rays 13(5), sometimes 12(1) in Quebec, 13(25), or 14(15), occasionally 15(7) in Ontario, Manitoba, and Saskatchewan. Scales cycloid, small, 61–72 in lateral line (58–76 in northwestern Canada, McPhail and Lindsey 1970), radii on all fields; lateral line straight or nearly so, complete. Peritoneum silvery, speckled with brown. Swim bladder not usually well developed in adults (Gee and Northcote 1963), extending only to about origin of pelvic fins. Vertebrae 37–41 (McPhail and Lindsey 1970, gave range of 40–42). But *see* vertebral variation with latitude in the table below.

Colour Colour of the back varies from olive-green to brown, shading to cream or silvery white on the belly; dark dorsal colour often ceasing abruptly below midpoint of sides. In lakes, the back is generally greyish. Sometimes there is a faint mottling formed by scattered, darkened scales, which are usually confined to midlateral pigmented area. Often a dark stripe ahead of the eye. Dark lateral line from gill cover to caudal base on fish from some areas, or only on posterior half on others, or may be absent, except on young which have a distinct lateral stripe from snout to tail.

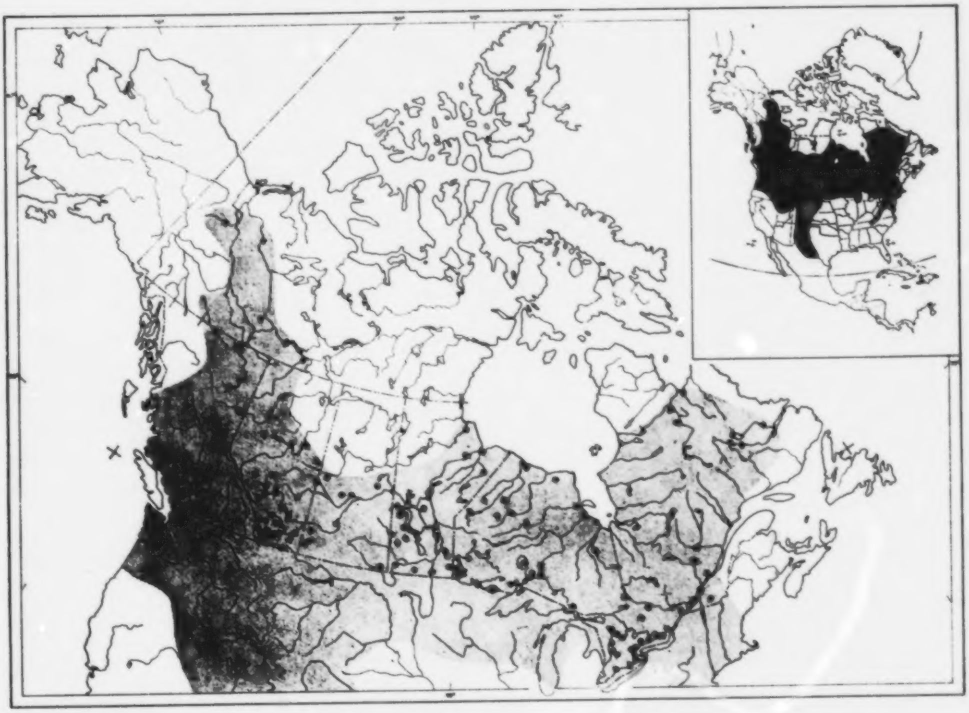
Breeding males in southern Ontario waters display an orange-red colouration on the corners of the mouth, spreading lightly onto cheeks, also in the posterior axils of the pectoral fins, a trace on the pelvics, and sometimes along the anterior base of anal fin. Keleher (1952a) noted that 10 specimens from Lake Winnipeg exhibited bright orange tinge on pectoral fins and premaxillaries.

Systematic notes The reduced size of the swim bladder in adult longnose dace has been known for many years, but it appears that there is much variation in the degree of its development from population to population. The failure of most adults to develop normal swim bladders was discussed by Bailey and Allum (1962), Gee and Northcote (1963), and McPhail and Lindsey (1970) (*see* these references for further information).

As noted by Radforth (1944), an understanding of the zoogeography of the longnose dace must await a systematic study of the species throughout its range. Such a study has still not been made. Note relatively low vertebral counts for Alberta specimens ROM 25921, given in *Description.*

Distribution The longnose dace is widely distributed from coast to coast in north-central North America. In the east, it occurs south along the mountains to Virginia; in the Mississippi drainage south to Iowa; and in the western basin south to northern Mexico; recently reported from northeastern

°N		ROM cat. no.	Vertebrae					
			37	38	39	40	41	42
43	Ont., Dufferin Cr.	24072		3	6			
45	Que., Rigaud R.	24021		4	4			
46	Ont., Stokely Cr.	16237			4	6		
51	Man.,Steeprock R.	18443			5	4	1	
57	Que., Whale R.	22533			2	1		
60+	McPhail and Lindsey (1970)					×	×	×
49	Alta., Bow R.	25921	1	3	4	2		



Nevada (Moore 1968). It occurs in the inshore waters in all the Great Lakes.

In Canada the species is found in swiftly flowing streams and also in lakes, from Labrador; the upper St. Lawrence River and Ungava drainages (Koksoak and Whale rivers) of Quebec; throughout the Great Lakes area, north to Hudson Bay in Ontario; common and widely distributed in Manitoba, Saskatchewan, Alberta; throughout most of British Columbia, from the Fraser and Columbia River systems north to the Peace and Liard rivers, and on the Pacific slope north to the Skeena River system. It occurs through the Mackenzie River system of Alberta, the Northwest and Yukon territories, to the Arctic Circle. Previous reports of its occurrence in New Brunswick were shown to be unverified by Scott and Crossman (1959). Neither does it occur in Nova Scotia nor Prince Edward Island.

The extremely wide range of the longnose dace creates a number of interesting zoogeographic problems. Radforth (1944) suggested an eastern postglacial refugium as well as a Mississippi one. McPhail and Lindsey (1970) suggested the Pacific region as a possible third refuge to survive glaciation. Its peculiar distribution in eastern Canada was discussed by Power (1965), who noted its apparent absence east of the Saguenay River in Quebec, yet its presence in the Ungava drainage of far northern Quebec suggests that if its absence from the interior is real, then the Ungava and Labrador populations must have survived from the period of the climatic optimum of some 4000–6000 years ago.

Biology Little has been written about the spawning habits of the longnose dace, which seems strange considering it is one of our most wide-ranging minnows. Spawning is usually considered to begin in May, June, or early July. (McPhail and Lindsey 1970 noted that it may continue into late August in Kananaskis Lake, Alta.) Carl et al. (1967)

noted that ripe males and females were taken at a temperature of 53° F (11.7° C) in the Nicola River drainage, British Columbia, June 7, 1956, and Dymond et al. (1929) reported ripe males and females taken at the mouth of the Credit River, Lake Ontario, July 16, 1927. Dymond (1926) gave June and July as the times of spawning in Lake Nipigon.

Spawning probably occurs in riffles over a gravelly bottom, but, on occasion, spawning must occur near or over the nest of the river chub, *Nocomis micropogon*, since hybrids have been reported. Indeed, this hybrid enjoyed the distinction of specific identity, *Rhinichthys bowersi* Goldsborough and Clark. (*See* Raney 1940b, for a complete account.) Hybridization with *Richardsonius balteatus* has also been reported (Carl et al. 1967), and with *Couesius plumbeus* (Hubbs and Lagler 1949). McPhail and Lindsey (1970) suggested that, although no nest is built, a territory is established and one parent guards the nest. They noted that in Manitoba, females laid 200–1200 transparent, adhesive eggs that hatched in 7–10 days at 60° F (15.6° C). The yolk sac is absorbed about 7 days after hatching and the young then rise to the surface and inflate the posterior lobe of the swim bladder. Fish (1932) described the chromatophore pattern of the larvae and figured a 13.7-mm specimen. The young are pelagic, unlike the adults, and inhabit quiet waters near shore. McPhail and Lindsey noted that the pelagic stage lasts about 4 months before the typical bottom-dwelling existence of the adults commences.

Apparently the longnose dace grows rather slowly. In Minnesota, they have been reported to grow to total lengths of 1.9 inches (48 mm) by age 1, 2.4 inches (61 mm) by age 2, 2.9 inches (74 mm) by age 3, 3.4 inches (86 mm) by age 4, and 3.9 inches (99 mm) by age 5 (Kuehn 1957). Scales were used for age determination. Maximum length of specimens in ROM collection is 4.9 inches (125 mm) from Manitoba and Lake Erie.

The longnose dace is characteristic of clean, swiftly flowing, gravel or bouldery streams, at times inhabiting very turbulent waters. They also occur in inshore waters of lakes over boulder or gravel bottoms. In warm lakes they may move offshore into deep water during the heat of summer as noted by Trautman (1957) for the Ohio waters of Lake Erie. Such offshore movements cannot be ascribed, without modification, to the Ontario shore east of Long Point. During investigations in 1946–1949, we seined longnose dace from sand–gravel–boulder beaches through June, July, and August.

The longnose dace is a benthic or bottom-living species and, hence, its food habits are directly related to bottom-living organisms. Dymond (1926) noted that chironomid larvae were the main food items in Lake Nipigon and one longnose dace had eaten eggs of another fish, presumably the trout-perch. Carl et al. (1967) gave midge larvae as the main food in British Columbia, supplemented by other aquatic insect larvae. Reed (1959) examined stomachs of 796 adults from Pennsylvania waters and reported that nearly 90% of the food consisted of adult or immature stages of blackflies (Simulidae), midges (Chironomidae), and mayflies (Ephemeroptera). The most comprehensive published food study of this species is that of Gerald (1966) for the Yellowstone River in Montana. He studied the diet for all sizes to 100 mm, from early July to September. He concluded that availability and abundance of the food organisms were the primary factors governing diet; simulid larvae, being in the fast-flowing water, were eaten mainly by the larger dace since the swift current would be a deterrent to small dace.

Bangham and Hunter (1939) examined 51 specimens of longnose dace from Lake Erie and found 17 infected variously with the trematodes *Neascus rhinichthysi* and *Lebouria cooperi* and the nematode *Camallanus oxycephalus*.

Bangham and Adams (1954), working with the species from the Columbia and Peace River drainages, found that 27 of 44 longnose dace were parasitized, but stated that the species frequently had few parasites.

Bangham (1955) reported the encysted larval form of the trematode *Posthodiplostomum minimum* in the five fish examined from

Pleasant Creek, near South Bay, Manitoulin Island, Ont.

Hoffman (1967) listed various forms of trematodes, nematodes, the protozoan *Cryptobia* sp., molluscan glochidia, and the crustacean *Lernaea cyprinacea* from longnose dace in unspecified North American waters.

Relation to man Despite its wide range and availability, the longnose dace is not, to our knowledge, a commonly used bait species in Canada, possibly because of its drab colouration and its intolerance of the still water of minnow pails. However, it is widely used as a bait fish in various parts of the United States. Simon (1946) remarked that it was of great value as a forage fish in Wyoming, and Iowa authorities stated that it was widely used in that state as bait for bass and catfish. Dobie et al. (1956) reported that it has been propagated at least once in Minnesota in long, narrow ponds having a weak flow of water.

Nomenclature

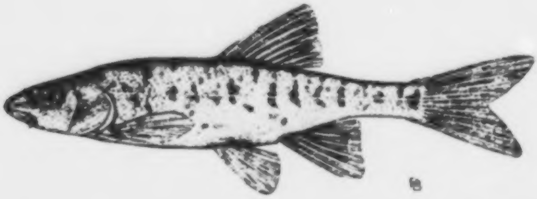
Gobio cataractae — Cuvier and Valenciennes 1842: 315 (type locality Niagara Falls)
Rhinichthys marmoratus — Agassiz 1850: 354
Argyreus nasutus — Cope 1869: 369
Rhinichthys cataractae (Cuvier & Valenciennes) — Jordan and Evermann 1896–1900: 306

Etymology *Rhinichthys* — snout; fish — the snout being prominent; *cataractae* — of the Cataract, the original type being from Niagara Falls.

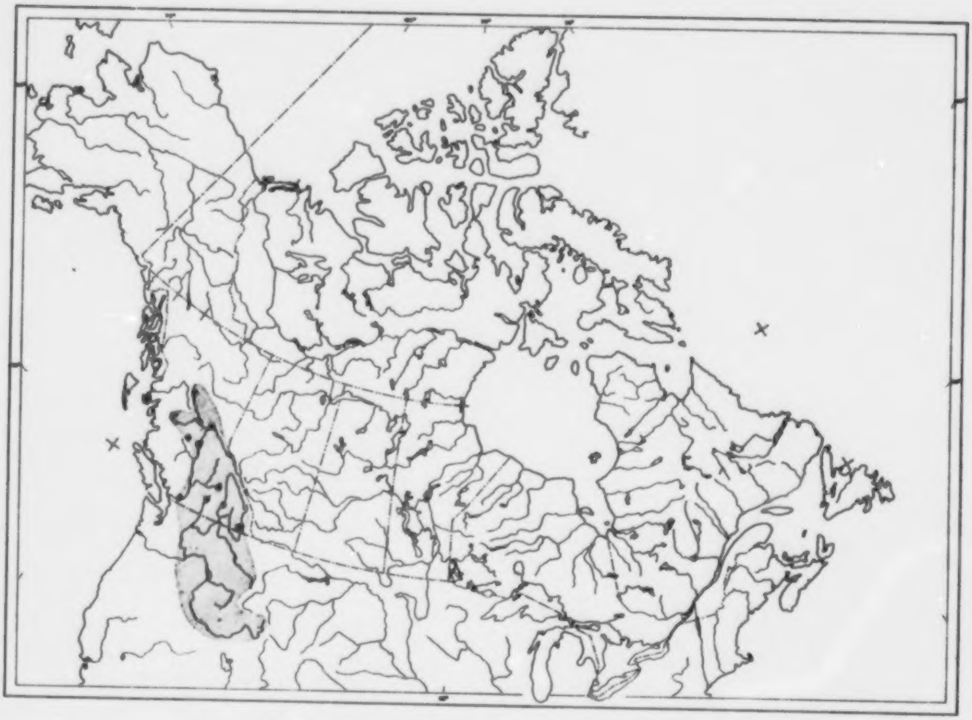
Common names Longnose dace, long-nose dace, long-nosed dace. French common name: *naseux de rapides*.

LEOPARD DACE

Rhinichthys falcatus (Eigenmann and Eigenmann)



Description Body elongate, total length averaging about 3 inches (76 mm), body distinctly heaviest before dorsal fin, somewhat compressed laterally, its depth 14.8–18.2% of total length; caudal peduncle very slender, distinctly compressed laterally. Head triangular, its length 19.1–21.7% of total length; eye diameter 20.0–27.7% of head



length; snout bluntly rounded, its length 31.3–36.8% of head length, slightly overhanging mouth; interorbital moderate, its width 26.6–30.0% of head length; mouth small, nearly horizontal, with a rather conspicuous barbel at each corner of the mouth; pharyngeal teeth usually 2,4–4,2. Fins: dorsal 1, trailing margin of fin slightly concave (i.e., fin sickle-shaped), origin of dorsal scarcely behind origins of pelvic fins, rays 9; caudal deeply forked, attached to a slender caudal peduncle; anal 1, its origin slightly in advance of dorsal fin insertion, rays 7; pelvics uniquely equipped with fleshy stays joining base of fin rays to surface of body, rays 8; pectorals rather small, more or less rounded, rays usually 14, range 13–15. Scales cycloid, radii absent on basal field, 52–57 in lateral line; lateral line complete, almost straight. The swim bladder is rather well developed (*see* Gee and Northcote 1963, for details). Vertebrae 38–40.

Fine tubercles developed on top of head, over back and sides, and on the upper surface of the pectoral fins (one male, ROM 18575, taken in the Nechako River, clearly shows fine tubercles on rays of pectoral fins, although none were observed by Gee and Northcote 1963).

Colour A light-coloured dace, creamy on the sides, somewhat darker on the back, especially on head where darker colouration extends to below the eye; and silvery white below; sides marked with many large (covering 4–8 scales) irregularly shaped spots. Yellowish tinge on fins. On breeding males, the lips and base of pelvic fins are orange-red according to Carl et al. (1967). Gee and Northcote (1963) observed this high colouration in all seasons.

Distribution The leopard dace occurs in the Fraser River system, and in the Columbia River basin east of the Cascade Mountains.

In Canada, it is known only from British Columbia. It occurs in Okanagan Lake, Lower Arrow Lake, Pend Oreille River, and possibly Similkameen River (Columbia system), and from various lakes and rivers in the Fraser River system. For details *see* Carl et al. (1967).

Biology The spawning habits of the leopard dace appear to be unknown but, by examining gonads, Gee and Northcote (1963) concluded that spawning occurred early in July.

These authors also used the length–frequency method to distinguish age-groups and calculated the following age–fork length relation: age 0 in August, 9–18 mm; age 1 in June, 18–36 mm; age 2 in June, 44–61 mm; age 3 in June, 60–80 mm; age 4+, 80–120 mm. They also concluded that females were heavier and slightly longer than males.

When leopard dace occur in the same river systems as the longnose dace, the two species have quite different current-flow preferences: *falcatus* prefers slow-moving currents, probably less than 0.5 metres/second, and the longnose prefers more rapid water.

Young-of-the-year feed almost entirely on dipterous larvae whereas yearling dace feed primarily on aquatic insect larvae (Ephemeroptera and Diptera predominate), especially during June and July. By September, these yearlings will switch to a diet of terrestrial insects. Adult dace age 2 and older, also eat aquatic insect larvae (Ephemeroptera and Diptera), some terrestrial insects, and also earthworms (*Lumbricus*) displaced from the soil by high water. *See* Gee and Northcote for a discussion of the differences in food and habitat of leopard and longnose dace.

The parasites of the leopard dace have apparently not been studied.

Relation to man It is not possible to evaluate the importance, if any, to man since we have so little information, but we know of no commercial importance associated with the leopard dace.

Nomenclature

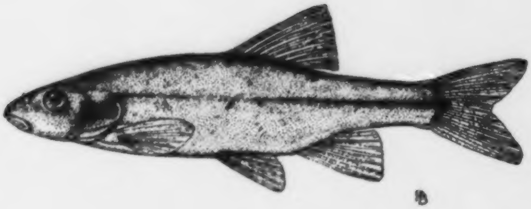
Agosia falcata	— Eigenmann and Eigenmann 1893a: 153 (type locality Boise River, Caldwell, Idaho)
Agosia shuswap	— Eigenmann and Eigenmann 1893a: 154
Apocope falcata (Eigenmann and Eigenmann)	— Jordan, Evermann, and Clark 1930: 141
Rhinichthys falcatus (Eigenmann and Eigenmann)	— Carl and Clemens 1948: 80

Etymology *Rhinichthys* — snout; fish — the snout being prominent; *falcatus* — sickle-shaped.

Common names Leopard dace, silvery grey minnow. French common name: *naseux léopard*.

SPECKLED DACE

Rhinichthys osculus (Girard)



Description Body elongate, 2–3 inches (51–76 mm) total length, greatest depth in front of dorsal fin, rather heavy bodied anteriorly, but distinctly compressed laterally behind dorsal fin, greatest body depth 15.8–20.0% of total length. Head bluntly triangular, a small but distinct hump behind the head, head length 21.1–24.1% of total length; eye moderate, its diameter 20.5–24.7% of head length; snout long and distinctly overhanging mouth; interorbital relatively narrow, its width 22.3–32.4% of head length; mouth inferior, sucker-like, lower jaw with fleshy lip, overhung by snout, extending back to about midnostril, 1 maxillary barbel at each corner of mouth in United States specimens but not on Canadian specimens, upper lip protractile, free from snout; pharyngeal tooth count variable throughout range, in Canada 1,4–4,1 to 2,4–4,2. Fins: dorsal 1, its origin distinctly behind pelvic fin origin, posterior margin straight, rays 8 or 9; caudal forked, lobes rounded; anal 1, its origin about under posterior base of dorsal fin, rays 6 or 7; pelvic fins relatively small, rounded, rays 8 or 9; pectorals small, rounded, rays 13 or 14. Scales cycloid, about 55–75 in lateral series; Carl et al. (1967) said 55–58 in British Columbia; lateral line complete, or terminating before base of caudal fin. Peritoneum uniformly dark brown or with darker patches. Vertebrae 37 or 38.

Colour Overall colouration grey or grey-brown with scattered and vague darker flecks, usually above midline of sides; lower sides and belly somewhat yellowish or creamy white. A faint lateral band beginning weakly under dorsal fin and extending onto caudal peduncle, terminating with a diffuse spot on caudal fin base; this spot and the lateral band are more conspicuous on young fish. Sigler and Miller (1963) reported that an orange-red colouration appeared about mouth, upper part of gill opening, anal base, and lower caudal lobe of spawning males in Utah, but such colours have not been reported for Canadian populations.

Distribution The range of the speckled dace is restricted to western North America, where it occurs in Pacific watersheds from the Columbia River south to the Colorado River system, and coastal streams and interior waters of southern California. It occurs also in the Chehalis River and in the Deschutes and adjacent rivers in Washington State (McPhail 1967). It is reported to be abundant in Wyoming, New Mexico, and the lower Colorado River (Miller 1952).

In Canada the species has been reported from only three localities along the Kettle River of the Columbia system in extreme south-central British Columbia at 49°N lat, 118°W long.

Biology Throughout its United States range, the speckled dace inhabits greatly diverse habitats and exhibits great differences in the morphological and meristic characters usually used to distinguish species. It seems likely that the form known as *Rhinichthys osculus* may include more than one species. For example, La Rivers (1962) treated four named subspecies for Nevada. Since we do not have detailed information on the biology of the British Columbia population, it would be misleading to suggest that the characteristics of speckled dace in Nevada or Utah could be applied. Carl et al. (1967) noted that in the Similkameen River, B.C., *R. falcatus* exhibited characters approaching those of *R. osculus*, and further that nothing seemed to be known of the life history, presumably of the northern populations, of speckled dace.

A variety of parasites, including protozoans, trematodes, nematodes, crustaceans, and molluscan glochidia were listed by Hoffman (1967) for the speckled dace, presumably from various populations in the United States.

Relation to man The speckled dace is of some importance as a forage species and is also widely used as a bait fish, in various parts of the western United States, although Miller (1952) questioned its suitability for bait because of its small size. According to Simon (1946) it is an important bait species in Wyoming.

It is not regarded as an important species in Canadian waters because of its limited occurrence.

Nomenclature

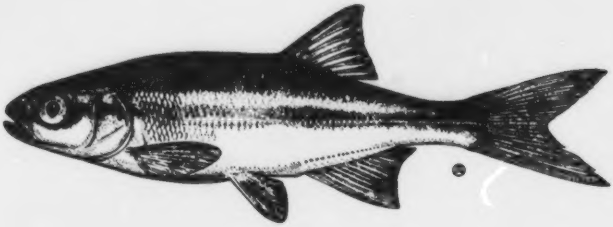
Argyreus osculus — Girard 1857a: 186 (type locality tributary of Rio San Pedro, Ariz.)
Agosia oscula (Girard) — Jordan and Evermann 1896–1900: 309
Apocope oscula (Girard) — Jordan, Evermann, and Clark 1930: 141
Rhinichthys nubilus (Girard) — Miller 1952: 30
Rhinichthys osculus (Girard) — Carl, Clemens, and Lindsey 1967: 123

Etymology *Rhinichthys* — snout; fish — the snout being prominent; *osculus* — small-mouthed.

Common names Speckled dace. French common name: *naseux moucheté*.

REDSIDE SHINER

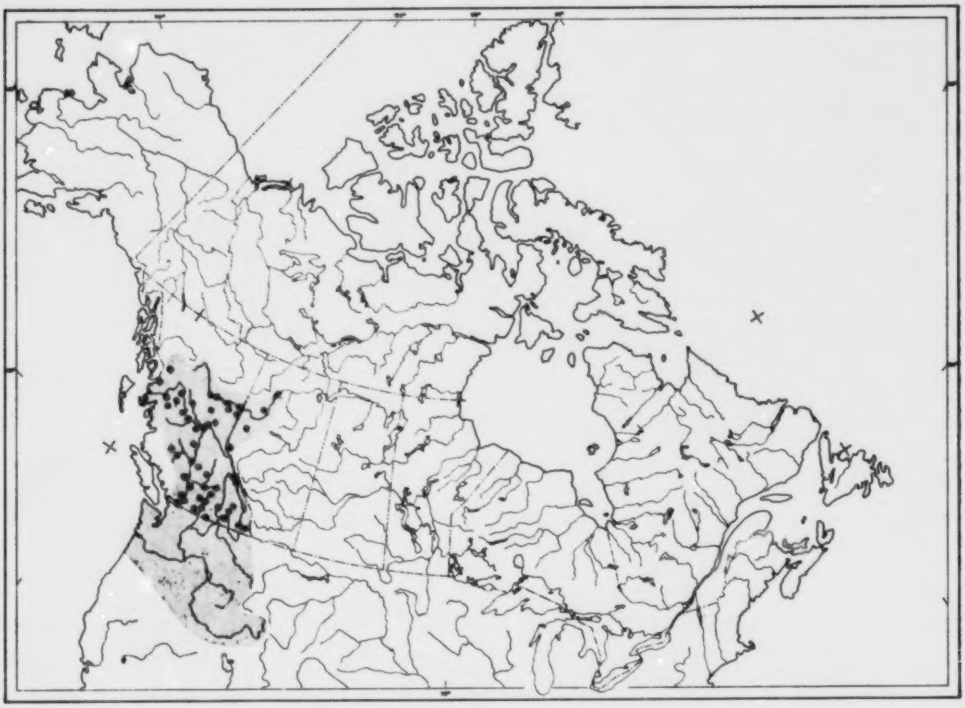
Richardsonius balteatus (Richardson)



Description Body variable but moderately deep, greatest depth, between paired fins, 20.8–24.7% of total length, moderately compressed laterally; caudal peduncle twice as long as deep; adults usually 3–5 inches (76–127 mm) in length. Head long, 18.0–20.5% of total length, wide, interorbital width 34.2–40.6% of head length; eyes large, diameter 25.5–33.3% of head length, forward of centre of head; snout moderately long, 28.5–34.2% of head length, about equal to eye diameter, bluntly pointed; mouth moderately large, maxillary extending almost to anterior edge of orbit, terminal and only slightly oblique; pharyngeal teeth in several combinations but usually 2,5–5,2, 2,5–4,2, without grinding surfaces, anterior tooth on left often shorter than others, remote from them and dagger-shaped. Gill rakers are short and stubby, 6–9 on first arch. Fins: dorsal 1, moderately large, at midpoint of body, origin well in advance of origin of anal fin, but behind insertion of pelvic fins, base length less than height, edge little curved, rays 8–12, usually 10; caudal long, deeply forked, tips pointed; anal 1, with long base but height about equal to base length, edge markedly falcate, number of rays high but extremely variable, usually 15, 13–18 in specimens examined, but 10–24 in Canada according to the literature, anal ray number often different between sexes in the same population; abdomen near anal fin somewhat keeled; pelvics abdominal, low, small, tips rounded, 8 or 9 rays; pectorals larger than pelvics, above ventral surface, tips with rounded points, 13–16 rays. Both pelvic fins and pectoral fins longer in males than in females. Scales cycloid, small, 52–67 in lateral series; lateral line complete, beyond pectoral fins straight and at midbody. Peritoneum pale, silvery, lightly speckled with black; intestine long and coiled. Vertebrae 38–43.

Nuptial tubercles on males only, on head and upper surface of paired fins.

Colour Dorsal surface of body and head steely blue, olive, or dark brown to black. On the flanks, below the countershading of the dorsal surface, is a narrow unpigmented band from operculum to dorsal fin. Below this, in the middle of the sides, is a dark band extending from snout to caudal peduncle, broadest below dorsal fin and often inconspicuous from head to tip of pectoral fins. Body below lateral band bright silver and ventral surface silver or white. Fins clear, amber to dusky. Eye with black pupil, a narrow, gold ring and white beyond, with pigmented patches carrying the lateral band through the eye. Both sexes more highly coloured at spawning time. The female is then a golden colour above and below the lateral band and on the head. The male is more strikingly coloured with a band of yellow between the dorsal countershading and the more intensified, dark lateral band. Below the lateral band is a broad stripe of orange to



crimson from the operculum to the anal fin, the lower part of the body is yellow, as is most of the head below the eye. The lower fins are a bright yellow, especially in males.

Systematic notes The great variation in anal fins in different localities over the range of this species and the possible correlation to subspecific entities, and such parameters as sex, latitude, altitude, and temperature have intrigued workers since Eigenmann in 1895 (Lindsey 1953; Weisel 1961). The variation in anal rays led to the designation of several species or subspecies including *balteatus*, *gilli*, *montanus*, *lateralis*, *thermophilus*, *hydrophlox*, and *siuslawi*. It is generally conceded now that only two main forms exist in the west, *R. balteatus* (10–24 anal rays) and *R. egregius*, the Lahontan redside (8 or 9 anal rays) (McPhail and Lindsey 1970).

Redside shiners are known to hybridize with northern squawfish, longnose dace, and peamouth chub.

Distribution This species is restricted to North America and occurs mainly west of the Rocky Mountains. It extends from the Peace River in northwestern Alberta throughout much of British Columbia from the Nass River south, coastal streams of Washington and Oregon, the Columbia River basin, the Malheur basin in Oregon and in the Bonneville River basin of Washington, Oregon, Idaho, Montana, Nevada, and Utah. Introduced into the Colorado River.

In Canada, it occurs in the Wapiti River system (Peace River) of Alberta south almost to Vermilion, west through British Columbia including the upper reaches of the Nass, Skeena, Klinaklini and Homathko rivers and the entire Fraser, and Columbia River systems; absent from Vancouver Island and other coastal islands.

Biology Contrary to the case for so many species, much is known of the biology of this cyprinid in Canada, largely as a result of interest in its morphological variability and ecological impact on trout. For detailed accounts, *see* Lindsey and Northcote (1963), Johannes and Larkin (1961), Crossman (1959a, b), Crossman and Larkin (1959), and Lindsey (1953). The following is largely from Lindsey and Northcote.

Spawning takes place in groups of 30–40 fish, in streams or in lakes, over a 7- to 10-week period from May to late July or early August. Adults move into spawning streams in the afternoon and evening as soon as stream water temperature exceeds 50° F (10° C). There is apparently a strong homing tendancy. Males arrive earlier than females. In streams, spawning takes place in riffles where water is as shallow as 4 inches (102 mm), during day and night. During spawning a female and one or two males thrash violently side by side for about 2 seconds. No nest is built. Egg number for females ranges from 829 to 3602. The eggs, which are released in lots of 10–20 at each spawning act at irregular intervals, are demersal and adhesive and adhere to the bottom gravel or vegetation. Eggs are 1.9–2.2 mm in diameter and have a pale yellow yolk. Hatching takes place from 3 days at 69.8° F (21° C) to 15 days at 53.6° F (12° C). At hatching, fry are 5.3 mm total length and lie dormant on the bottom, feeding on the yolk for a week. In areas where stream spawning takes place, the fry are carried downstream at night by the stream current, about 10 days after hatching. They are in a very immature state when they reach the lake so they must be displaced very soon after hatching. By 10 days, when they begin feeding, they are 8.7 mm long. Age determination by scales is apparently difficult and uncertain. Size frequencies have been used but these yield only approximate results as growth rates differ greatly from year to year and from one location to another. An approximation of age–fork length relation at midsummer for Sixteen Mile Lake, B.C., is shown in the following table.

Age	FL	
	(inches)	*(mm)*
0	0.2–0.4	5–10
1	1.0–2.1	25–55
2	2.1–2.7	55–70
4+	4.3+	110+

An individual from Shumway Lake, B.C., 6.7 inches (170 mm) in total length, was judged to be 6 or 7 years of age. Females grow faster and live longer, so most of the very large and old individuals are females. Maximum age varies from place to place but probably does not exceed 7 years. Maximum size is 7 inches (180 mm) but most individuals are 3–5 inches (76–127 mm) in length. They appear to attain larger sizes in British Columbia than in areas to the south.

Sexual maturity is apparently first attained in the third year. In any summer the same mature individuals, particularly males, may return to the spawning grounds more than once, may spawn several times in one season and the production of eggs and sperm may be more or less continuous (Weisel and Newman 1951). As high as 46% of the spawners of any single year live to spawn again the following year, and some may survive to spawn even a third time.

This minnow occurs, often in schools numbering in the thousands, in large lakes, moderately fast streams, and small ponds, with widely varying temperature and trophic conditions. In lakes there is a vertical and horizontal stratification of sizes, the smallest are highest and closest to shore. In the daytime in summer, shiners are found only inshore, over shoals (2–12 feet deep) that have heavy growths of food-producing, rooted vegetation. They are rarely seen more than 25 feet beyond these shoals except at night when they move out in the top layer of the deeper water, often to the centre of the lake. Other than spawning migration, there appears to be little directed movement, except for a seasonal one, on and off the shoals in response to water temperatures. Upper lethal temperature for this species has been calculated as 77° F (25° C) when the fish were acclimated at 48°–52° F (8.9°–11.1° C).

Redside shiner fry feed on diatoms, copepods, ostracods, and other small planktonic and demersal crustaceans. Larger shiners are mainly insectivorous, and they consume terrestrial insects such as beetles and ants that fall to the surface of the water but consume mainly adult and immature forms of most aquatic insects; algae; molluscs; fish eggs; and small fishes including other redside shiners, other minnows, and trout. Egg predation by redside shiners may be one of the most limiting factors on the survival of their own eggs. They are active foragers, working right into the vegetation for food, and often crop off food organisms at sizes too small for other more economically important species (such as trout) to utilize.

This species is preyed on by a variety of fishes including rainbow trout, cutthroat trout, probably Dolly Varden, and squawfish; by many fish-eating waterfowl such as mergansers and loons; and by mink if not other mammals. Redside shiners are serious competitors for food and space with species of trout.

Incidence of parasitism is often very high in the dense schools of this species, both in variety and number. Older fish are often bloated by the presence of one or more large cestodes, *Ligula intestinalis*. Parasites appear often to be both a direct and an indirect cause of death. Redside shiners bearing large *Ligula* move more slowly or tumble down through the water and more easily fall prey to trout. Bangham and Adams (1954) examined 1532 specimens of redside shiners from the Columbia, Fraser, Skeena, and Peace River drainages, and found 1493 heavily infected. Many varieties of trematodes, cestodes, crustaceans, nematodes, acanthocephalans, etc., were identified. Hoffman (1967) listed the following for the species throughout its range: Trematoda (11), Cestoda (5), Nematoda (6), Acanthocephala (1), Mollusca (1), Crustacea (1).

Relation to man The interest in this species, which has led to a great deal of study and which, in effect, constitutes a statement of its relation to man, was succinctly expressed by Lindsey and Northcote (1963) as follows: "It has received attention from some biologists because of its spectacular but puzzling morphological variation, and from others because of its well-documented impact on sport fisheries for rainbow trout. It has so far defied most attempts of the former to rear it, and of the latter to eradicate it."

In lakes where it has accidentally entered a habitat previously exploited by trout alone it has had serious effects on the growth rate and production of the trout. The redside shiner in lakes like Paul Lake near Kamloops, B.C., can develop populations as high as 5000–100,000 per acre and then constitute a minor predator on, a serious competitor of, and a substantial food for rainbow trout. The effect on the trout population has led to costly and disruptive attempts at chemical eradication, which destroy the existing trout also. This leads to the requirement for extensive fish cultural support to renew the fishery. The Paul Lake example of the drastic consequences of such an introduction was dealt with in detail by Larkin and Smith (1954), and by the authors listed at the beginning of this species account.

Nomenclature

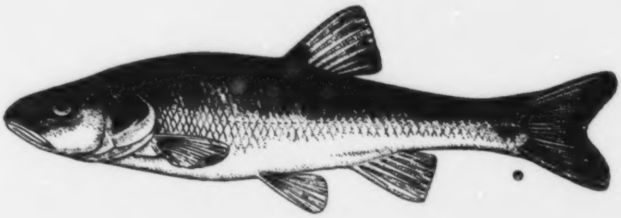
Cyprinus (*Abramis*) *balteatus* (Rich.) — Richardson 1836: 301 (type locality Columbia River)
Richardsonius balteatus — Girard 1857a: 202
Richardsonius lateralis — Girard 1857a: 202
Abramis lateralis — Günther 1868: 309
Abramis balteatus — Günther 1868: 309
Leuciscus balteatus (Richardson) — Eigenmann 1895: 112
Leuciscus balteatus lateralis (Girard) — Eigenmann 1895: 113

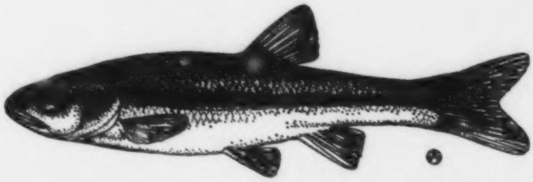
Etymology *Richardsonius* — after Sir John Richardson, surgeon–naturalist with the Franklin expeditions, who first described it; *balteatus* — girdled.

Common names Redside shiner, red-sided bream, Columbia River minnow, Richardson's minnow, silver-sided minnow, shiner, silver shiner. French common name: *méné rose.*

CREEK CHUB

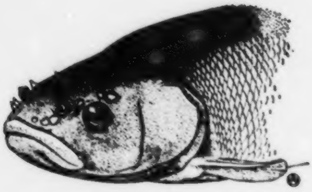
Semotilus atromaculatus (Mitchill)





Description Body thickset, robust, average length to about 4 inches (102 mm), not noticeably compressed laterally except caudal peduncle, greatest body depth at about tip of depressed pectoral fin 17.0–26.1% of total length. Head broad, heavy, its length 21.4–25.3% of total length; eye relatively small, its diameter 15.1–26.6% of head length; snout moderate to large, 29.1–36.6% of head length, upper lip projecting slightly beyond lower or equal; interorbital broad, its width 35.2–44.5% of head length; mouth large, gape wide, upper jaw reaching to a point below pupil, upper and lower lips thick, lower not included but upper lip projecting slightly or equal; premaxillaries protractile, a flaplike barbel located in groove between maxillary and premaxillary, in advance of posterior end of maxillary, seldom absent; pharyngeal teeth usually 2,5–4,2 but variable, 2,4–4,2, 2,4–5,2, strong, hooked. Fins: dorsal 1, its origin slightly behind pelvic fin origin, small, rays almost always 8(93), rarely 9(2), a distinct and obvious black spot at base of first 3 rays; caudal slightly forked, lobes rounded; anal 1, small, unpigmented, its origin slightly overlapped by free margin of depressed dorsal fin, rays 8(92), rarely 7(1), or 9(1); pelvics small, origin slightly in advance of dorsal origin, rays 8(30); pectorals small, rounded, rays usually 17(13), 16(10), or 15(4), seldom 13(1), 14(1), or 18(1). Scales cycloid, persistent; lateral line usually complete, sometimes interrupted, scales 53–61. Peritoneum silvery with light speckling; intestine short, a single loop.

Vertebrae usually 42(28) or 43(14), but sometimes 40(9) or 44(4), seldom 39(1) or 40(1). There appears to be a tendency for counts to be slightly higher in western populations.



Nuptial tubercles large, sharp, and well developed on head and dorsal surface of pectoral fins of males. On head, 6–10 or 12 on each side, extending backward from upper lip, in a single line on each side of head, in line with nostril, and arching over orbit, small but well-developed tubercles on opercle, extending onto opercular membrane, tubercles on first 6–8 rays of pectoral fin, in single row.

Colour Back olive to olive-green, silvery on the sides and silvery white below. The sides often show violet or purple iridescence. There is a conspicuous and characteristic black spot at the anterior base of the dorsal fin.

Breeding males usually have a rosy cast but may also exhibit tints of orange, yellow, blue, and purple on the body, especially on sides of head and body, and sometimes on fins. The young (*see* lower illustration p. 507) are silvery in appearance, are not noticeably compressed laterally, and have a narrower lateral band than fallfish (*S. corporalis*), which commences behind the eye and terminates in a small discrete spot on caudal fin base (Hubbs and Cooper 1936).

Systematic notes Two subspecies have been described for the creek chub. The typical subspecies, *S. a. atromaculatus* (Mitchill), is considered to occupy all of the range except in the extreme southeastern United States, where the species is represented by *S. a. thoreauianus* Jordan. Bailey et al. (1954) considered that the difference in scale size, which was the major distinguishing feature, was clinal in nature and that subspecific distinctions were unwarranted.

Natural hybrids in the following combinations have been reported: *Clinostomus elongatus* × *S. atromaculatus* (Greene 1935), *Notropis cornutus* × *S. atromaculatus* (Raney 1940a; Greeley 1938).

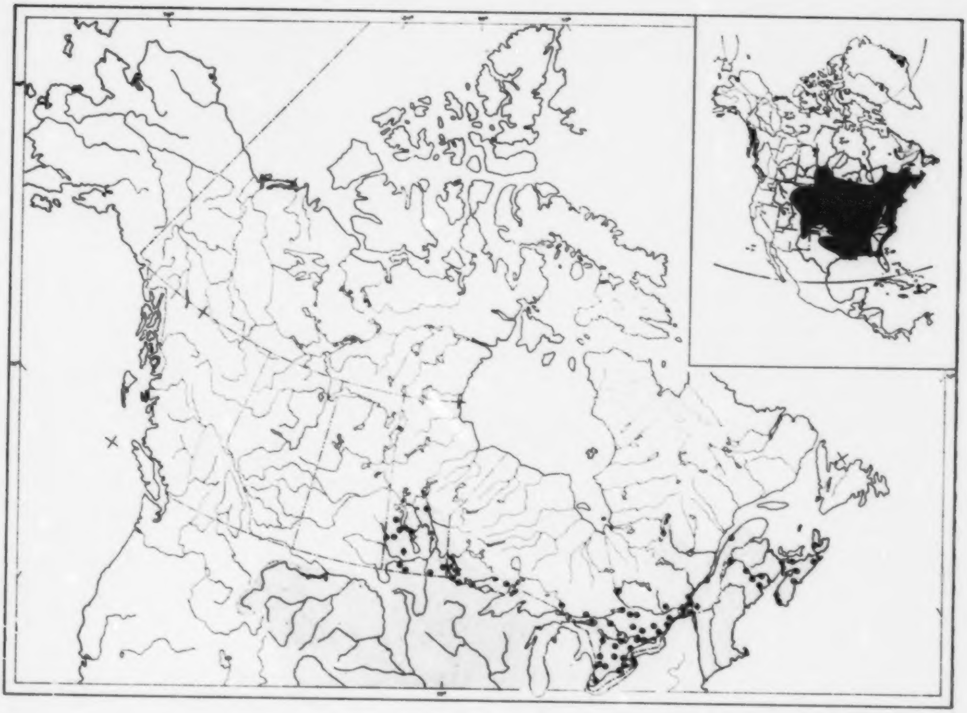
Distribution The creek chub is found in small clear brooks from the Gaspé Peninsula to Montana, south on both sides of the Appalachian Mountains to Georgia and the Gulf states, southwesterly to northeastern Texas, and New Mexico. Not to Alberta nor to Newfoundland as reported by Carlander (1969).

In Canada it is widely distributed in many lakes and streams throughout the eastern and central portions. Common in Nova Scotia, except on the plateau of northern Cape Breton, wide ranging in New Brunswick in all major river systems north to and including the Miramichi and probably including the Restigouche River system; in Quebec from Gaspé west in the St. Lawrence drainage system and in the Saguenay River system including Lake St. John, and the James Bay drainage of Rupert River, Lake Wakonichi, where it was common in 1944. It occurs throughout Ontario in suitable habitats, north to the Algoma District, and in the Rainy River District, but not in region north of Lake Superior.

It reaches its western limit in Canada in the Assiniboine River in Manitoba. Collected in western tributaries in lakes Manitoba, Dauphin, Swan, and Winnipegosis, and tributaries of the Red and Assiniboine rivers, but not east of Dominion City.

Biology The creek chub is probably the most common stream minnow in eastern North America and one that has been widely used for bait, hence, its life history has received considerable attention.

Spawning occurs in the spring, usually beginning at temperatures of 55° F (12.8° C) and above. Spawning sites are most often selected in rather small, gravelly streams in smooth water just above or below a riffle. The male creates a pit or depression in the stream



bottom by vigorously swimming against the bottom, and by picking up stones in his mouth and carrying them a short distance upstream. By excavating downstream and depositing upstream, he digs a trench that is constantly being filled in. Spawning occurs in the pit, the eggs dropping quickly to the bottom and then being covered with stones carried from the downstream end of the pit. The trench or pit is usually 10–12 inches wide and may be many feet long. The male spawns with several females, meanwhile continuing to expand the trench downstream and cover it and the eggs upstream, and, of course, guarding the nest against invading males at all times. When spawning is completed the eggs are thus buried under the stones and gravel and the completed nest appears as a long gravel ridge.

Each nest is usually the work of one male but in large streams with good gravel substrate, there may be several nests side by side.

In Canada spawning occurs during May and June and into July but surprisingly few observations have been published. Richardson (1935) considered spawning to have been mainly completed by mid-June in the eastern townships of Quebec.

The spawning act was fully described in a classical paper by Reighard (1910). The female approached the pit of the nest, the male remained near the bottom. Eventually, the female approached the male who reacted, in Reighard's words, as follows: "Usually when she has come near enough, the male gets his head and his expanded pectoral fin of one side beneath her, and then with a movement often too rapid to be followed by the eye, he tosses her into an upright position and at the same time encircles her body with his own." This brief embrace requires only about a tenth of a second, and is made possible by the tubercles on the pectoral fin, opercle, and body of the male. During the embrace, about 50 eggs or fewer are emitted by the female, are fertilized, and sink into the nest or the upper slope. After the spawning act, the female floats for a moment, belly up, as if dead, and then swims off. Each female spawns a number of times, in the same or a different nest, continuing to spawn over a period of many days until all ripe eggs are extruded.

The early life-history stages were described by Fish (1932), who also provided a figure of the 14-mm stage.

Growth is rapid, young chub attaining a length of 2.0–3.5 inches (51–89 mm) the first year, and 4–7 inches (102–178 mm) at the end of the fourth year. Females usually mature in the third year, males in the fourth in Michigan. Males continue to grow and attain a maximum length of about 12 inches (305 mm), a weight of about 12 ounces (340 g), and an age of about 7 years, whereas females are smaller, 7–8 inches (178–203 mm) and reach a maximum length of 11 inches (279 mm) in Michigan; in Ohio, females reach a maximum length of 9.5 inches (241 mm). The largest specimen from Canadian waters known to us is a male 9.8 inches (248 mm) in total length from a stream near Holt, Ont., although longer ones are to be expected.

In a study of 76 creek chub from Quebec waters, Leonard (1927) concluded that none were older than 3 years but his age determinations seem questionable. Considerable data on lengths and weights were provided.

The creek chub seems to prefer small, clear, streams and brooks, although it does inhabit the shore waters of small lakes. It is one of the most common minnows in the populated regions of Ontario and those to the east.

Its omnivorous food habits are doubtless partly responsible for the considerable success the species enjoys. It has been classified as a sight feeder by Evans (1952), which is in keeping with the clear-water habitat preferred. Young chub eat planktonic organisms, consuming larger organisms as they grow. Aquatic and terrestrial insects larvae and adults (such as beetles, mayflies, caddisflies, and chironomids) form a major part of the diet and large males will also eat crayfishes and small fishes. A food study of Quebec creek chub by Leonard (1927) indicated the importance of insects in the diet but showed also that cladocerans, algae, and higher plant tissues were significant.

A large number of species of parasites infecting creek chub are listed in the literature, much too extensive to repeat here. Hoffman (1967), for example, listed over 30 species. Regional studies by Bangham and associates should be consulted also: Bangham and Hunter (1939) for Lake Erie, Bangham and Venard (1946) for Algonquin Park, Ont., and Bangham (1955) for Lake Huron region.

A new species of monogenetic trematode, *Octomacrum semotili*, from the gills of creek chub in Algonquin Park lakes, was described by Dechtiar (1966b).

Relation to man The creek chub is one of our most important bait minnows because it is hardy, grows to a large size, and can be readily caught in most streams within its region of distribution. Although almost all chub sold in Canada are "wild" fish, they can be reared artificially. Dobie et al. (1956) described in considerable detail how they can be spawned and reared in a hatchery type operation.

The creek chub used to be one of the first fishes caught by small boys and still provides considerable enjoyment to youthful anglers, for it will eagerly take a baited hook. Although somewhat small and bony, the flesh has a fine flavour.

Chub are consumed by a variety of natural predators such as loons, kingfishers and mergansers (White 1953, 1957). They probably do not compete seriously with brook trout because they occupy the warmer sections of streams but their diet is competitive with the brown trout to some extent, although the trout tend to occupy larger water courses than those preferred by the creek chub.

Nomenclature

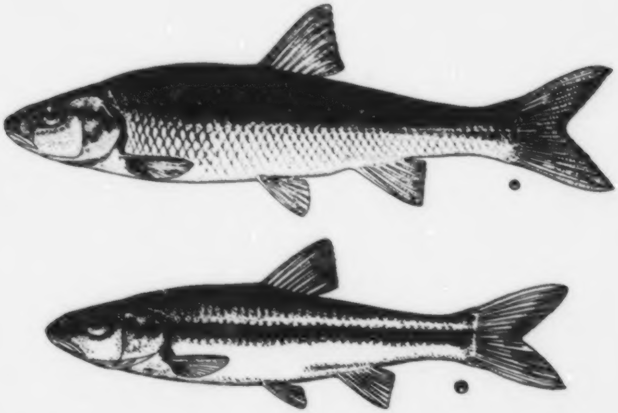
Cyprinus atromaculatus — Mitchill 1818a: 324 (type locality Wallkill River, N.Y.)
Semotilus dorsalis — Rafinesque 1820c: 49
Leuciscus cephalus — Perley 1852: 194
Leuciscus atromaculatus DeKay — Fortin 1866: 72
Semotilus atromaculatus — Bicknell and Dresslar 1886: 16
Semotilus corporalis Mitchill — Cox 1896b: 65

Etymology *Semotilus* — banner (i.e., dorsal fin); the second part of the word was used elsewhere by Rafinesque to mean 'spotted'; *atromaculatus* — *ater* —black, *macula* — spot.

Common names Creek chub, horned dace, chub, common chub, northern creek chub, tommycod, brook chub, silvery chub, mud chub, blackspot chub. French common name: *mulet à cornes*.

FALLFISH

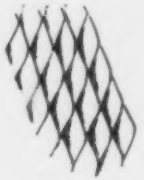
Semotilus corporalis (Mitchill)



Description Body somewhat compressed laterally, elongate, average length about 4 inches (102 mm) but grows to over 12 inches (305 mm), greatest body depth 17.0–21.1% of total length. Head bluntly pointed, its length 20.1–23.7% of total length; eye somewhat larger than for *atromaculatus*, its diameter 17.3–29.4% of head length; snout moderate to large, its length 28.5–40.5% of head length, slightly projecting beyond upper lip; interorbital broad, but less so than *atromaculatus*, its width 32.0–41.1% of head length; mouth slightly subterminal, overhung by snout, and lower lip included in upper lip, upper jaw reaching barely to the anterior margin of orbit, premaxillaries protractile, a slender flaplike barbel in groove between maxillary and premaxillary in advance of posterior end of maxillary, usually not well developed and often absent on one or both sides, but usually apparent on large adults; pharyngeal teeth usually 2,5–4,2 but variable and may be 2,4–5,2, 2,4–4,2. Fins: dorsal 1, its origin directly over pelvic origin, or more nearly so than either on *margarita* or *atromaculatus*, dorsal larger, rays always 8(53); caudal distinctly forked, lobes pointed; anal 1, large, slightly falcate, its origin not quite overlapped by depressed dorsal fin, rays usually 8(48), seldom 7(6) or 9(1); pelvics well developed, origin about under dorsal fin origin, rays usually 8(36), seldom 9(3); pectorals moderate, pointed, rays 16(12), 17(11), or 18(16) but regional differences exist, and counts appear to be higher in Maritimes. Scales cycloid, large, and characteristically pigmented (*see* following sketch) with crescent-shaped pigmented areas on anterior field; lateral line complete, scales 43–50. Peritoneum silvery, scattered speckles; intestine short, single main loop. Vertebrae usually 43(20), sometimes 42(9) or 44(1).

Nuptial tubercles small, but not minute; on spawning males, on snout extending posteriorly in two lateral patches to surround nostrils and continue toward orbit, a single row of small tubercles on dorsal arc of orbit, a patch of fine tubercles on lower posterior edge of opercles and on adjacent branchiostegal rays, decreasing in extent medially. Fine tubercles also on opercular flap and on adjoining lateral aspect of trunk, on skin but not on scales; on first 7–9 rays of pectoral fin a single row of fine tubercles, extending along length of ray, including its branches; no tubercles evident on dorsal or pelvic fins.

Colour Back olive-brown to black, sides silvery and underparts silvery white. Scales on adult fallfish present a characteristic pattern consisting of a series of dark, crescent-shaped or triangular black bars at the base of each scale along the sides. Large adults, quite silvery in overall appearance, are usually called silver chub by trout fishermen who catch them unintentionally. Young fish, 4 inches (102 mm) or less in length are also silvery, appear moderately laterally compressed, and have a pronounced wide lateral band that is evident on the head behind the eye, extending the length of the body and usually terminating in a rather large black spot on the posterior caudal peduncle. *See* lower illustration p. 511.

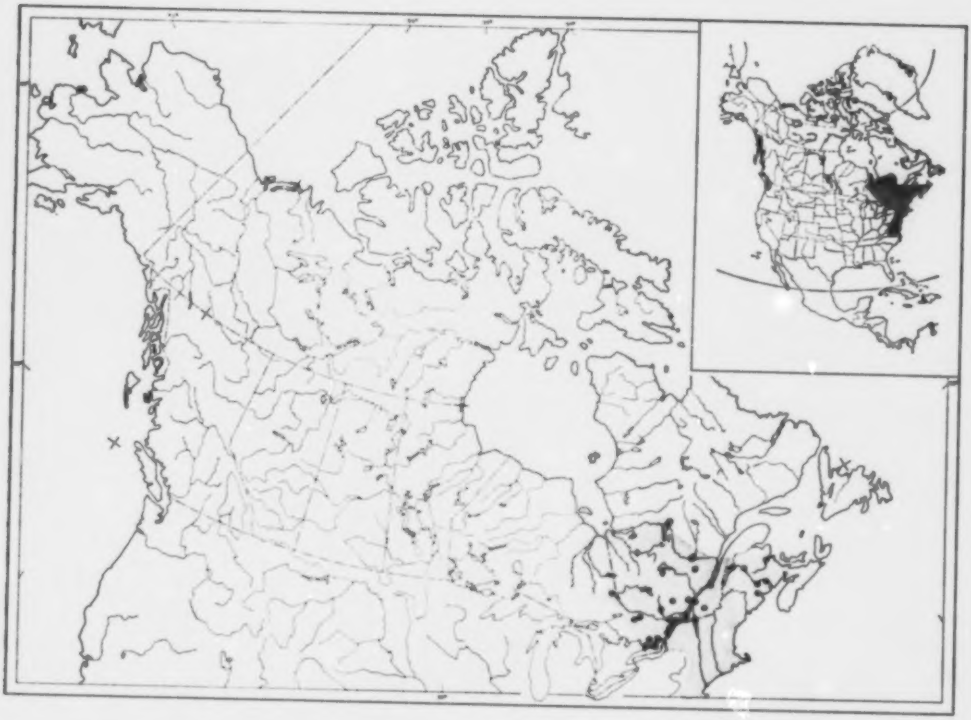


Distribution The fallfish occurs in clear streams and lakes south from New Brunswick, Quebec, and Ontario, east of the Appalachians, to Virginia.

In Canada, the species is common in some parts of New Brunswick as far north as the Miramichi River system but there are no records of it in the Petitcodiac, Nepisiguit, or Restigouche River systems (Scott and Crossman 1959). It is common in the waters of the St. Lawrence River drainage in Quebec, north to the James Bay watershed of Quebec and Ontario; in Lake Wakonichi of the Rupert River system of Lake Mistassini; in Ontario through the Ottawa valley and north to the Petawawa River drainage in Algonquin Park, and west along the north shore of Lake Ontario to at least the Trent River.

The record of a fallfish from Cedar Creek, Thunder Bay District, Lake Superior drainage, published by Allin (1951), was based on a misidentification. The specimen in question is a creek chub, *Semotilus atromaculatus*.

Biology The fallfish spawns in the spring over a pile of stones in the gravel bottom of a flowing stream. This mound of



stones is a nest, which is built by the male, carrying the stones in his mouth.

As is so often the case, there are few published Canadian observations on the biology of this species. In the eastern townships in Quebec, Richardson (1935) reported that nest building commenced in a stream tributary to Brome Lake on May 19 while the water temperature was only 53.6° F (12° C). Spawning commenced on May 20, at a temperature of 61.9° F (16.6° C). The nonadhesive eggs were deposited into elongate mounds of gravel, averaging about 2 feet (61 cm) long, and were covered with gravel after spawning. Richardson noted that a completed nest was somewhat conical in shape, averaging 4 feet (121.9 cm) in diameter and 2 feet (61 cm) high. The size of the nest was dependent on the sizes of the constructing male, which in that case ranged from about 6.1 to 7.4 inches (155–188 mm) long. Raney (1949), who worked mainly in New York State, considered the nests to be elongate, and to be characterized by a keel-like crest, which could be either in line with the current or crosswise to it. Raney examined several nests that were 6 feet (183 cm) in diameter and reached a height of 3 feet (91.5 cm), probably built by males measuring 15–18 inches (381–457 mm) in length. Nests of comparable size were built in eastern Ontario streams by fish of comparable sizes. Toner (1943) examined several nests believed built by this species in Spectacle Lake Creek, Leeds County, Ont. He caught several large fallfish nearby but could find no eggs in the nests.

Fallfish nests are sometimes used by spawning common shiners, *Notropis cornutus*, occasionally resulting in *N. cornutus* × *S. corporalis* hybrids (Greeley 1938).

Few figures on egg number are available but Richardson reported an average of 2300 eggs per female from fish of about 6.7 inches (170 mm) long. Data on time to hatching are sparse, but the same author noted that the head and tail were free in the majority of eggs 2 days after spawning. He also noted that larvae 12 mm long were present in a nest on June 6 and left the nest 2 days later. Young attained a length of 35 mm by the end of the first summer. Mansueti and Hardy (1967) illustrated and described a juvenile (about 93 mm total length) from the Chesapeake Bay region. There are few data available on maximum size attained, but the largest specimen on hand measured 16.6 inches (420 mm) long and weighed about 1.75 pounds (794 g). It was caught in Fire River, a tributary of the Missinaibi River, Ont. Actual lengths and weights of fallfish from the Petawawa River, Ont., taken in 1936 by J. R. Dymond, were as follows: 10.4 inches (265 mm) and 11.75 ounces (333g); 8.8 inches (225 mm) and 8.5 ounces (241 g); 8 inches (202 mm) and 4.25 ounces (120 g). Small (1883) noted that the average "full size" in the Ottawa region was "1 to 1½ pounds in weight."

The fallfish inhabits clear, flowing, gravel-bottomed streams and also lakes. The young inhabit the more rapid water upstream but large adults seem to seek large pools and expanded regions of the lower reaches. In Quebec, fallfish are frequently found in lakes but they are more common in rivers and streams in Ontario. In eastern United States waters, Trembley (1960) noted that they were seldom found in water over 82.4° F (28° C), which may not be applicable to Canadian populations.

The food of the fallfish in Canada is practically unknown but we assume that aquatic insect larvae, terrestrial insects (taken on surface), crustaceans, and fishes are important in the diet. They are quick to take an angler's trout fly and, hence, probably do take insects on the surface.

Fallfish fall prey to fish-eating birds in New Brunswick (and doubtless elsewhere within their range) according to reports by White (1953, 1957), who found their remains in the stomachs of eastern belted kingfishers and American mergansers.

Bangham and Venard (1946) examined 67 fallfish in lakes in Algonquin Park, Ont., and found 47 infected variously with nematodes, trematodes, cestodes, and copepods. The most common parasites were the nematode *Rhabdochona cascadilla*, which occurred in 32 specimens, and the trematodes *Allocreadium lobatum* and *Posthodiplostomum minimum* found in 24 and 10 specimens, respectively.

Hoffman (1967) listed a number of trematodes, one cestode, nematodes, acanthocephalans, and crustaceans from various parts of the range.

Relation to man Fallfish, sometimes called silver chub and other names by sport fishermen, are often caught by anglers fly fishing for trout and at times cause considerable annoyance, especially if they occur in numbers. Since adult fallfish attain weights in excess of 1 pound, they may be fished for sport in their own right. The flesh is firm, white, and sweet. We have no information on the use of young fallfish for live bait.

Nomenclature

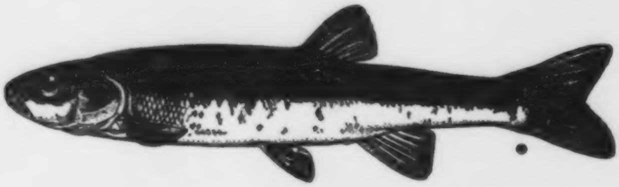
Cyprinus corporalis — Mitchill 1817: 290 (type locality Wallkill River, N.Y.)
Cyprinus bullaris — Rafinesque 1817b: 120
Leuciscus nitidus — DeKay 1842: 209
Leuciscus pulchellus — Perley 1852: 193
Leuciscus argenteus — Perley 1852: 194
Leuciscus canadensis — Fortin 1866: 70
Semotilus corporalis Mitch. — Cox 1893: 40
Semotilus bullaris (Raf.) — Cox 1896b: 65
Leucosomus corporalis (Mitchill) — Jordan, Evermann, and Clark 1930: 117

Etymology *Semotilus* — banner (i.e., dorsal fin); the second part of the word was used elsewhere by Rafinesque to mean 'spotted'; *corporalis* — pertaining to the body (Mitchill called the fish corporal or corporaalen).

Common names Fallfish, American chub, mohawk, white, silvery or roughnosed chub, dace, windfish, corporal, chivin, whiting, chub, shining dace. French common name: *ouitouche*.

PEARL DACE

Semotilus margarita (Cope)



Description Body elongate, average length about 3.5 inches (89 mm), body not deep, almost cylindrical, greatest depth 15.9–21.0% of total length, caudal peduncle long and rather slender. Head small, its length 19.0–23.6% of total length; eye relatively small, its diameter 21.8–30.7% of head length; snout somewhat rounded, its length 26.9–35.2% of head length; interorbital moderate, its width 31.5–38.8% of head length; mouth moderate, upper jaw reaching to a point below anterior nostril, lower lip included by upper lip, which projects slightly beyond snout and lower lip; premaxillaries protractile, and with a small flaplike barbel usually pigmented but variously developed and sometimes entirely lacking on one side, or even both sides; pharyngeal teeth usually 2,5–4,2, but some variability observed, 2,4–4,2, 2,4–4,1. Fins: dorsal 1, its origin behind origin of pelvic fins, small, rays usually 8(100), rarely 7(5); caudal fin shallowly forked, lobes rounded; anal 1, small, rays usually 8(93), sometimes 7(12); pelvics relatively small, rays usually 8(27), sometimes 9(2); no pelvic axillary process; pectorals well developed, anterior rays often stiffened and thickened in males as in *Chrosomus*, rays more often 15(11), or 16(8), but may be 14(1), 17(5), 18(3), or 19(1). The counts seem to be higher in the Maritimes (16–19) than in Manitoba (14–16). Scales cycloid, persistent, specialized darkened scales variously scattered on sides, especially on Maritime specimens, less so on western specimens; lateral line usually complete, sometimes discontinuous in young specimens. Peritoneum silvery, with speckling on dorsal part; intestine with a single loop, its length usually less than body length. Vertebrae 38(2), 39(27), or 40(15).

Nuptial tubercles not well developed, but those on first 6, 7, or 8 pectoral rays are better developed than others, in a single row on each ray but appearing as a double row when rays divide. A few minute tubercles on head.

Colour Overall colouration dark or dusky silver. Back dark, sometimes almost black, the sides silvery, the belly silver-grey to white. Specialized, darkened scales along sides may be absent but specimens from Ontario and eastward are often densely speckled. Dark lateral band on side distinct on young, and usually terminating with a distinct spot at base of caudal; lateral band indistinct on large specimens but often distinct on caudal peduncle.

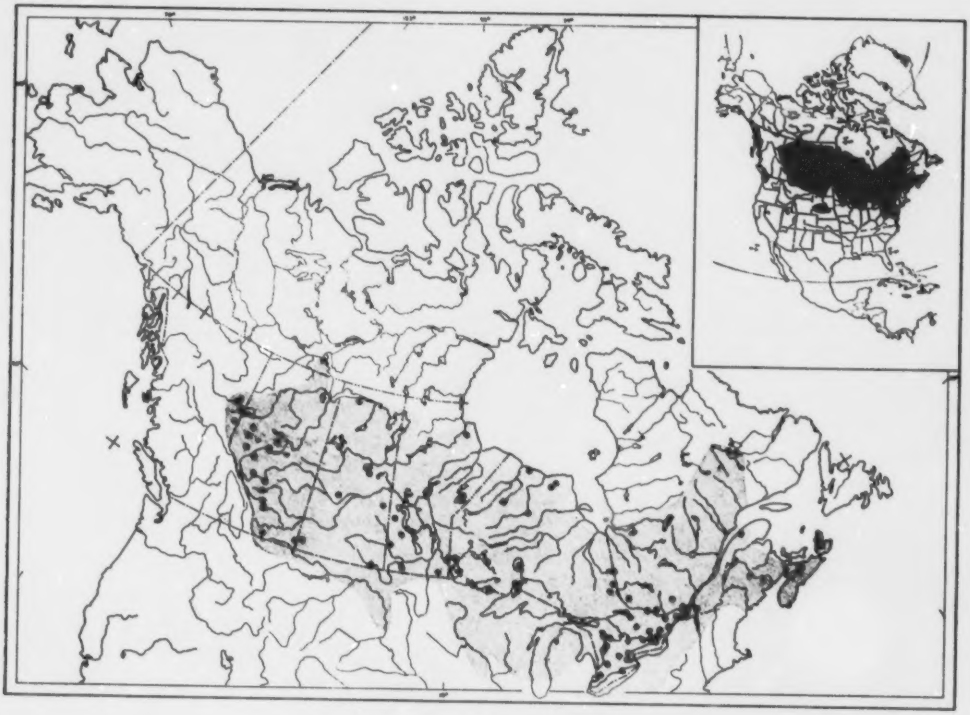
Adult males may be brilliantly coloured from late fall until almost midsummer, with a rich orange-red flush along the flanks commencing at the lower edge of the lateral band and spreading ventrally, leaving only a pale, central strip between head and anal fin but extending onto ventral surface of caudal peduncle.

Systematic notes The nomenclatural history of the pearl dace reflects the interest the species has aroused among ichthyologists, and something of its complexity. *See* Hubbs (1926) for a review of the early nomenclature and a diagnosis of the genus *Margariscus*. Bailey and Allum (1962) presented convincing reasons for the lumping of the genera *Margariscus* and *Leucosomus* (for *L. corporalis*) in the genus *Semotilus*, although many authors had accepted this change earlier (Hubbs and Lagler 1958; Blair et al. 1957; Moore 1968). We are aware of no published records of hybridization involving *Semotilus margarita*. One such reported case involving *Couesius* (Schultz 1941) was thoroughly reviewed by Hubbs (1942), who concluded the specimens in question were misidentified. Hubbs noted that female *S. margarita* and male *Couesius* tend to be intermediate between male *S. margarita* and female *Couesius*.

A number of subspecies have been proposed for the pearl dace: *S. m. margarita* (Cope), the Alleghany pearl dace, the typical subspecies, occurs from Vermont and New York south to Virginia; *S. m. nachtriebi* (Cox) the northern pearl dace, occurs through most of Canada from the Maritime Provinces to British Columbia, and barely enters the Northwest Territories; Hubbs and Lagler (1949) described *S. m. koelzi*, the Harvey Lake pearl dace, from a single lake on Isle Royale, Lake Superior; another subspecies, *S. m. athabascae* (Bajkov), was described by Bajkov (1927) from the Jasper region of Alberta. The primary features distinguishing the various subspecies are the number of scales (larger for *S. m. margarita*, than the others); *S. m. koelzi* differs from all others in having a more slender head. *See also* McPhail and Lindsey (1970) for additional discussion.

A thorough study of the species throughout its Canadian range is required. It is to be expected that northern Canadian populations will exhibit a lower scale count than southern ones as illustrated in the following table giving east–west trend of lateral line scale count of Canadian populations and for *S. m. margarita* and *S. m. nachtriebi*.

	Lateral Line Scales																				
	49	**59**	**60**	**61**	**62**	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**	**74**	**75**	**76**	**77**	**78**
Semotilus m. nachtriebi																					
N.S. (ROM 22842) N=9					1		3	1	4												
Ont. (ROM 19790) N=10									2	3	1	1	1		1		1				
Man. (ROM 17488) N=10														2	1	1	2	2	1	1	
Semotilus m. margarita	←→ (95% *S. m. margarita* range 49–62)																				
Semotilus m. nachtriebi					←→ (95% *S. m. nachtriebi* range 62–78)																



There also appears to be an interesting east–west trend suggested by pectoral ray counts of 29 specimens.

	Pectoral fin rays					
	14	15	16	17	18	19
N.S., South Margaree R.			1	4	3	1
Ont., Frontenac Co.		3	6	1		
Man., Silcox Creek	1	8	1			

Distribution The pearl dace occurs in cool bog ponds, creeks, and lakes, throughout most of Canada and in the United States from Maine south to Virginia, west in Vermont, New York State, Pennsylvania, northern Michigan, most of Wisconsin, in Minnesota, North Dakota, and northern Montana. Relict populations exist in cool springs in South Dakota and Nebraska.

In Canada, the species ranges from Nova Scotia, west through New Brunswick, Labrador, Quebec, Ontario, north to the Lake Nipigon and Lake Abitibi regions, through Manitoba, Saskatchewan, Alberta, to British Columbia where it has been taken in the drainages of the Athabasca, Peace, and Slave rivers. Pearl dace occur in the Northwest Territories from the lower Sass River southward. Its Canadian distribution appears to bear a relation to 55°–60° F July isotherm (Ryder et al. 1964; Loch 1969).

Biology Despite its extensive Canadian range, no thorough study of the biology of the pearl dace appears to have been undertaken. Published accounts about the pearl dace all rely heavily upon observations made by T. H. Langlois on the Pentwater River, and Pine Creek, Michigan, on June 12 and 13, 1928 (Langlois 1929), and few supplementary or corroborating observations have been made, which should surely be a challenge to present day biologists.

The pearl dace spawns in spring. Langlois noted that temperatures of 63° and 65° F (17.2° and 18.3° C) prevailed in Pentwater

River and Pine Creek, respectively. The brilliantly coloured males did not build nests, but maintained territories about 8 inches (203 mm) wide, and seemed not to maintain territories closer together than 6 feet (1.83 m). Spawning took place in clear water 18–24 inches deep on sand or gravel in a weak or moderate current, facing into a current, when present. Males spent much time off territories, but when home, nosed over the bottom as if, Langlois thought, looking for eggs to eat. Invading male dace are pursued or escorted away, but a ripe female may be driven onto the territory. The spawning act apparently occurred when the enlarged pectoral fin of the male was placed beneath the female's body anteriorly, with the caudal fin of the male placed over the caudal peduncle of the female. The male's tuberculate pectoral fin undoubtedly helps him to maintain this position, which possibly functions to stretch the female's ventral surface and aid in extrusion of the eggs. The spawning act, signified by the vibrating bodies of the mated pair, lasted for about 2 seconds, although Langlois did not observe the actual deposition of eggs. Each female repeated the act many times with different males and, hence, must deposit only a few eggs each time. Each egg measured 0.036 inches (0.9 mm) in diameter, and 1686 eggs were contained in a female 4.25 inches (108 mm) long.

The growth rate of pearl dace is not known but studies by Loch (1969) for a few Ontario populations suggested the following lengths: age 1, 55–65 mm; age 2, 75–95 mm; age 3, 95–120 mm. Females probably grow faster and live longer than males. The pectoral fins exhibit sexual dimorphism at maturity, which was attained at a length of about 65 mm. The largest specimens available to us were caught in Lundy Lake, Timiskaming District, Ont., and measured 6.1 inches (155 mm) long. A large collection from Crevice Lake, Algonquin Park, Ont., contains a number of specimens over 5.25 inches (134 mm) long, but the largest single specimen is one 6.25 inches (158 mm) in total length, reported by Lindsey (1956).

The habitat of the pearl dace in Canada is typically cool, clear headwater streams in the south, bog drainage streams, ponds, and small lakes in the north, and in stained, peaty waters of beaver ponds, in association with *Chrosomus* spp., *Pimephales promelas*, and *Culaea inconstans*.

The food is said to consist of copepods, cladocerans, and chironomids (Carlander 1969), but McPhail and Lindsey (1970) reported the occurrence of beetles, filamentous algae, and *Chara* in dace stomachs.

The pearl dace is probably an important forage species in Canadian waters, but the species is not readily identified in stomach content materials and confirming data are lacking. White (1953) noted its occurrence in the diet of kingfishers in New Brunswick and Nova Scotia, and it is probably also eaten by mergansers inland, although White (1957) found no evidence in Maritime collections.

Bangham and Venard (1946) examined 35 pearl dace from Algonquin Park and found 27 infected variously with trematodes and nematodes. Hoffman (1967) also listed protozoans, trematodes, and a nematode, *Rhabdochona cascadilla*, from this species.

Relation to man The importance of the pearl dace is difficult to assess. It is abundant in bog ponds and slow-moving streams in various parts of the central portion of Ontario and neighbouring Quebec and in many areas is an important bait minnow. It is usually unrecognized and included with finescale dace, redbelly dace, and creek chub, and sold as chub or dace. It is also used as a bait minnow in Alberta.

Nomenclature

Clinostomus margarita	— Cope 1869: 377 (type locality tributary of Conestoga River, Lancaster, Pa.)
Leuciscus nachtriebi	— Cox, U. O., 1896: 605

Couesius plumbeus Agassiz	— Cox 1896a: 41
	— Cox 1896b: 65
	— Cox 1899: 148
Leuciscus margarita (Cope)	— Jordan and Evermann 1896–1900: 241
Couesius plumbeus rubrilateralis	— Cox 1901: 42
Margariscus	— Cockerell 1909: 217 (as subgenus)
Leuciscus nachtriebi Cox	— Halkett 1913: 62
Leuciscus rubrilateralis Cox	— Cox 1921: 66
Margariscus margarita (Cope)	— Jordan 1924: 70
Leuciscus neogaeus Meek and Clark	— Hubbs 1926: 33
Leuciscus carletoni Kendall	— Hubbs 1926: 33
Semotilus margarita (Cope)	— Bailey et al. 1960: 17

Etymology *Semotilus* — banner (i.e., dorsal fin); the second part of the word was used elsewhere by Rafinesque to mean 'spotted'; *margarita* — a pearl.

Common names Pearl dace, nachtrieb dace, northern pearl dace, northern minnow, northern dace. French common names: *mulet perlé, mulet perlé du nord.*

TENCH

Tinca tinca (Linnaeus)

Description Body thickset, heavy, and laterally compressed, average total length 8–10 inches (203–254 mm), the caudal peduncle characteristically deep and short. Head triangular, its length about 28% of standard body length; eye orange-red in colour, small; snout relatively long; interorbital broad; mouth terminal, small in size with thick lips and a pair of well-developed barbels, one at each corner of the mouth; pharyngeal teeth 0,5–4,0 or 0,5–5,0. Gill rakers about 13. Fins: all fins dark and rounded; dorsal 1, rounded, rays 9; caudal shallowly forked, the lobes rounded; anal 1, rounded, rays 7 or 8; pelvic fins rounded, adult males with thickened second ray, not present in females nor immature fish; pectoral relatively short, rounded. Skin thickened, slimy; the scales small, embedded, 95–105 in lateral line; lateral line complete. Vertebrae 38 or 39.

Colour Overall colouration olive-green, at times dark green or almost black, with golden reflections on the flanks and darker golden reflections on ventral surface. Fins dark. European breeders have developed a golden variety.

Distribution The tench inhabits the flatland rivers and lakes of Europe northward usually to 61°N. In Asia it occurs in the Arctic Ocean drainage including the basins of the Ob and Yenisei, but is rare in Lake Baikal.

Introduced into North America, it now occurs in several areas including the Columbia

River system, streams and lakes in the Puget Sound drainage, and elsewhere in the United States such as the Potomac River and near Baltimore, Md.

In Canada the species occurs only in British Columbia, where it is found in Christina, Tugulnuit, and Osoyoos lakes in the Columbia River system. There are unverified reports of its occurrence on Vancouver Island (Carl et al. 1967). Dymond (1936) wrote that the species was first noted in Christina Lake about 1915.

Dymond (1936) stated tench were originally brought to Seattle for the World's Fair (prior to 1915) (the 1909 Alaska–Yukon Pacific Exposition?), and afterwards dumped into a large goldfish pond on the University of Washington campus. From there they were introduced to the Columbia River system where they made their way into Christina and other lakes of the Columbia system. Carl et al. (1967) stated that first introductions in the area were made about 1895 in small lakes of Spokane County, Wash. and Washington County, Ore.

Biology Little has been written about the biology of the tench in British Columbia waters, but its biology in European waters is well known. There, spawning usually occurs in weedy shallows during June or July, and large numbers of eggs (275,000 per pound of body weight) are deposited. The eggs are small, about 1 mm in diameter. Breder and Rosen (1966) provided a concise review of the European literature on spawning. Tench grow to about 9 or 10 inches (229–254 mm) long and a weight of 0.75 pounds in about 4 years, at which time they may be mature. They are said to have a life expectancy of 20–30 years.

The tench is regarded as a slow-moving, sluggish fish that prefers mud-bottom ponds or the still waters of the lower reaches of rivers where rooted aquatic plants grow in profusion.

Maximum sizes in Canadian waters have not been reported, but Dymond (1936), quoting Schultz, noted that specimens nearly 2 feet long were taken in Union Lake, Wash. Wheeler (1969) gave the weight of the British angling record as 8 pounds 8 ounces (3.85 kg).

The diet is reported to consist mainly of aquatic insect larvae and molluscs; only the young fish consume algae to any degree.

Jenkins (1958) said they are preyed upon by predatory fish like the northern pike, but large tench probably have few enemies except man.

The parasites listed by Hoffman (1967) included a variety of trematodes, nematodes, crustaceans, protozoans, acanthocephalans, and a leech, *Piscicola geometra*.

Relation to man In Europe the tench has a following of devoted anglers and it is also regarded as a useful fish for pond culture, often in association with carp. By others it is esteemed as a food fish. The golden variety is used to stock ornamental ponds. However, it appears to have none of these attributes in British Columbia waters, nor in any North American waters, and is generally ignored.

Nomenclature

Cyprinus Tinca	— Linnaeus 1758: 321 (type locality Europe)
Tinca vulgaris Cuv.	— Day 1880–1884: 188
Tinca tinca (Linnaeus)	— Carl and Clemens 1948: 75

Etymology *Tinca* — Latin name for tench.

Common names Tench. French common name: *tanche*.

Suggested Reading — Cyprinidae

Black, J. D. 1945. Natural history of the northern mimic shiner. Invest. Indiana Lakes Streams 2(18): 449–469.

Cooper, G. P. 1936. Age and growth of the golden shiner (*Notemigonus crysoleucas auratus*) and its suitability for propagation. Pap. Mich. Acad. Sci. Arts Lett. 21: 587–597.

Dobie, J., O. L. Meehean, S. F. Snieszko, and G. N. Washburn. 1956. Raising bait fishes. U.S. Fish Wildl. Serv. Circ. 35: 123 p.

Forney, J. L. 1968. Raising bait fish and crayfish in New York ponds. N.Y. State Coll. Agr. Cornell Ext. Bull. 986: 31 p.

Gee, J. H., and T. G. Northcote. 1963. Comparative ecology of two sympatric species of dace (*Rhinichthys*) in the Fraser River system, British Columbia. J. Fish. Res. Bd. Canada 20: 105–118.

Gerald, J. W. 1966. Food habits of the longnose dace, *Rhinichthys cataractae*. Copeia 1966: 478–485.

Gibbs, R. H., Jr. 1957. Cyprinid fishes of the subgenus *Cyprinella* of *Notropis*. II. Distribution and variation of *Notropis spilopterus*, with the description of a new subspecies. Lloydia 20: 186–211.

Gilbert, C. R. 1964. The American cyprinid fishes of the subgenus *Luxilus* (genus *Notropis*). Bull. Fla. State Mus. Biol. Sci. 8: 95–194.

Harrington, R. W., Jr. 1947. The breeding behavior of the bridled shiner, *Notropis bifrenatus*. Copeia 1947: 186–192.

1948. The life cycle and fertility of the bridled shiner, *Notropis bifrenatus* (Cope). Amer. Midland Natur. 39: 83–92.

Hervey, G. F., and J. Hems. 1968. The goldfish. Faber and Faber, London. 271 p.

Hubbs, C. L., and G. P. Cooper. 1936. Minnows of Michigan. Cranbrook Inst. Sci. Bull. 8: 95 p.

Jenkins, R. E., and T. Zorach. 1970. Zoogeography and characters of the American cyprinid fish *Notropis bifrenatus*. Chesapeake Sci. 11: 174–182.

Lachner, E. A. 1952. Studies of the biology of the cyprinid fishes of the chub genus *Nocomis* of northeastern United States. Amer. Midland Natur. 48: 433–466.

Lachner, E. A., and R. E. Jenkins. 1967. Systematics, distribution, and evolution of the chub genus *Nocomis* (Cyprinidae) in the southwestern Ohio River Basin, with the description of a new species. Copeia 1967: 557–580.

Lindsey, C. C., and T. G. Northcote. 1963. Life history of redside shiners, *Richardsonius balteatus*, with particular reference to movements in and out of Sixteenmile Lake streams. J. Fish. Res. Bd. Canada 20: 1001–1030.

Lord, R. F., Jr. 1927. Notes on the use of the blackhead minnow, *Pimephales promelas*, as a forage fish. Trans. Amer. Fish. Soc. 57: 92–99.

McCann, J. A. 1959. Life history studies of the spottail shiner of Clear Lake, Iowa, with particular reference to some sampling problems. Trans. Amer. Fish. Soc. 88: 336–343.

McCrimmon, H. R. 1956. Fishing in Lake Simcoe. Dep. Lands Forests, Toronto, Ont. 137 p.

1968. Carp in Canada. Fish. Res. Board Can. Bull. 165: 93 p.

Olund, L. J., and F. B. Cross. 1961. Geographic variation in the North American cyprinid fish, *Hybopsis gracilis*. Univ. Kans. Publ. Mus. Natur. Hist. 13(7): 323–348.

PATTEN, B. G., and D. T. RODMAN. 1969. Reproductive behavior of northern squawfish, *Ptychocheilus oregonensis*. Trans. Amer. Fish. Soc. 98: 108–111.

PEER, D. L. 1966. Relationship between size and maturity in the spottail shiner, *Notropis hudsonius*. J. Fish. Res. Bd. Canada 23: 455–457.

PFEIFFER, REV. R. A. 1955. Studies on the life history of the rosyface shiner, *Notropis rubellus*. Copeia 1955: 95–104.

RANEY, E. C. 1940a. The breeding behavior of the common shiner, *Notropis cornutus* (Mitchill). Zoologica 25: 1–14 + 4 pls.

1940b. *Rhinichthys bowersi* from West Virginia a hybrid, *Rhinichthys cataractae* × *Nocomis micropogon*. Copeia 1940: 270–271.

1942. Propagation of the silvery minnow (*Hybognathus nuchalis regius* Girard) in ponds. Trans. Amer. Fish. Soc. 71: 215–218.

REED, R. J. 1957. Phases of the life history of the rosyface shiner, *Notropis rubellus*, in northwestern Pennsylvania. Copeia 1957: 286–290.

1959. Age, growth, and food of the longnose dace, *Rhinichthys cataractae*, in northwestern Pennsylvania. Copeia 1959: 160–162.

REIGHARD, J. E. 1910. Methods of studying the habits of fishes with an account of the breeding habits of the horned dace. Bull. U.S. Bur. Fish. 28: 1111–1136 + pl. 114–120.

1943. The breeding habits of the river chub, *Nocomis micropogon* (Cope). Pap. Mich. Acad. Sci. Arts Lett. 28: 397–423.

SHEPPARD, J. D. MS 1969. Some aspects of the life histories of the golden shiner (*Notemigonus crysoleucas* (Mitchill) and the common shiner (*Notropis cornutus* (Mitchill)) in eastern Ontario, with particular reference to growth. M.Sc. Thesis, Queen's University, Kingston, Ont. 324 p.

SIGLER, W. F. 1958. The ecology and use of carp in Utah. Utah St. Univ. Logan Agr. Exp. Sta. Bull. 405: 63 p.

SMITH, L. L., JR., and R. H. KRAMER. 1964. The spottail shiner in Lower Red Lake, Minnesota. Trans. Amer. Fish. Soc. 93: 35–45.

SUTTKUS, R. D. 1958. Status of the nominal cyprinid species *Moniana deliciosa* Girard and *Cyprinella texana* Girard. Copeia 1958: 307–318.

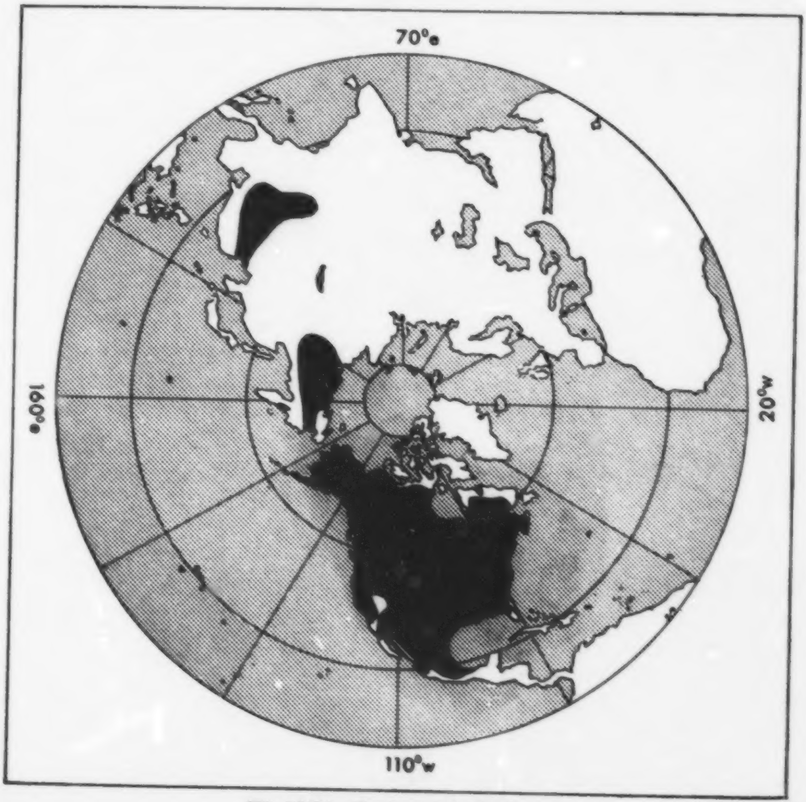
VAN DUZER, E. M. 1939. Observations on the breeding habits of the cutlips minnow, *Exoglossum maxillingua*. Copeia 1939: 65–75.

SUCKER FAMILY — Catostomidae

Small, to moderately large, subcylindrical, to laterally compressed fishes. Mouth characteristically ventral, subterminal, and protrusible (except in *Ictiobus*). Head short and broad; lips large, thick, usually papillate, lower lip cleft. Jaw teeth absent, lower pharyngeals with numerous, large, comblike teeth in a single row. No barbels. No adipose fin; pelvic fins low; caudal fin forked; and dorsal fin in centre of body. Swim bladder physostomous, large, and with 2 or 3 chambers.

Fishes of rivers and lakes of North America, eastern Siberia, and China. A large family, mainly North American, of 10 genera and about 65 species. One species *Catostomus catostomus* occurs in both Asia and North America.

Known from the Eocene to Recent in Asia and Miocene or possibly Eocene to Recent in North America.



World Distribution of the Suckers

KEY TO SPECIES

1 Dorsal fin with long base and more than 20 rays, first 4–7 rays of dorsal extended to form pointed or rounded lobe at least as high again as rest of fin; distance from insertion of dorsal to origin of caudal less than dorsal fin base ... 2

Dorsal fin with short base and fewer than 20 rays, no rounded or pointed anterior lobe, rays a uniform gradation in length; distance from insertion of dorsal to origin of caudal greater than dorsal fin base ... 3

2 Dorsal fin with moderate anterior lobe, first ray about 3 times as long as shortest dorsal ray; mouth horizontal to oblique, terminal or nearly so, little overhung by snout, mouth larger (maxillary twice eye diameter); caudal fin with shallow fork ... BIGMOUTH BUFFALO, *Ictiobus cyprinellus* (p. 557)

Dorsal fin with very high, pointed, anterior lobe, first ray at least 4–6 times as long as shortest dorsal ray; mouth horizontal, inferior, and markedly overhung by snout, mouth small (maxillary about equal to eye diameter); caudal fin with deep fork ... QUILLBACK, *Carpiodes cyprinus* (p. 528)

3 Lateral line present; snout rounded; mouth horizontal, inferior, and overhung by snout; greatest body depth less than one-third the body length to end of scales ... 4

Lateral line absent; snout broadly pointed; mouth oblique and only subterminal, not noticeably overhung by snout; greatest body depth one-third, or greater than one-third, of body length to end of scales; dorsal fin appears large for body length; wide, horizontal, mid-lateral, black band except in largest specimens; usually no more than 5–6 inches (120–150 mm) in length ... LAKE CHUBSUCKER, *Erimyzon sucetta* (p. 551)

4 Sides of body with prominent spotted pattern, approximately 10 horizontal rows of dark spots about the size of the pupil, one on each scale ... SPOTTED SUCKER, *Minytrema melanops* (p. 561)

No such pattern of small spots ... 5

5 Head large and broad, depression between eyes; eyes very high and past midpoint of head; snout long and markedly turned down; body pattern of dark blotches and 3 wide, oblique bars; usually not over 8 inches (200 mm) in length ... NORTHERN HOG SUCKER, *Hypentelium nigricans* (p. 554)

Head flat or rounded on top; eyes lower, and approximately in middle of head ... 6

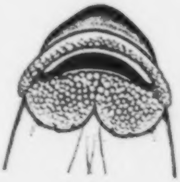
6 Scales small, usually more than 55 in lateral line; swim bladder with 2 chambers; body cylindrical (*Catostomus*) 7

Scales larger, fewer than 50 in lateral line; swim bladder with 3 chambers; body subcylindrical to laterally compressed (*Moxostoma*) 11

7 Scales small, usually over 90 in lateral line (rarely to 87 in *C. columbianus*) ... 8

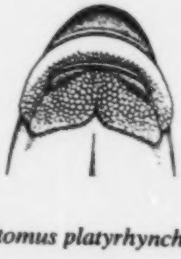
Scales larger, usually fewer than 90 in lateral line (rarely to 108 in *C. platyrhynchus*) 9

8 Lower lip not completely cleft, 3 rows of papillae cross ahead of the base, 3 or 4 rows of papillae on upper lip; cartilagineous edge of jaws obvious inside lips when mouth open; sometimes a notch at point of lateral connection of upper and lower lips; least caudal peduncle depth less than one-half length of dorsal base; membranous connection between base of pelvic fins and body (*see* illustration in couplet 10); not over 15 inches (375 mm) in length .... BRIDGELIP SUCKER, *Catostomus columbianus* (p. 536)



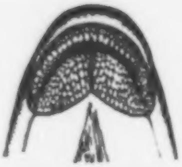
Lower lip completely cleft, no rows of papillae cross ahead of base, at most 1 row of small papillae on floor of cleft, only 2 rows of papillae on upper lip; cartilagineous edge of jaw not conspicuous without pulling lips back; never a notch at point of lateral connection of upper and lower lips; least caudal peduncle depth more than one-half length of dorsal base; no membranous stays between pelvic fins and body .... LONGNOSE SUCKER, *Catostomus catostomus* (p. 531)

9 Lower lip incompletely cleft, usually 3 or 4 rows of papillae crossing ahead of base; cartilagineous edge of jaws visible inside lips when mouth open; pronounced notch at point of lateral connection of upper and lower lips; anterior margin of upper lip not papillate, no upper lip papillae visible from front; more than 15 oblique rows of scales from lateral line to origin of dorsal; usually not more than 8 inches (200 mm) in length .... MOUNTAIN SUCKER, *Catostomus platyrhynchus* (p. 547)

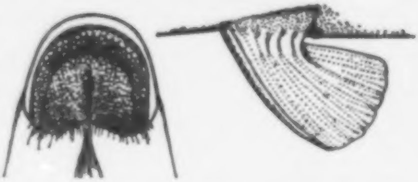


Lower lip completely cleft, usually no rows of papillae crossing ahead of base (rarely 1 or 2 rows on base in *C. macrocheilus*); cartilagineous edge of jaws not conspicuous; no notch at point of lateral connection of lips; papillae of upper lip visible from front; fewer than 15 oblique rows of scales from lateral line to origin of dorsal; size at least to 24 inches (610 mm) in length 10

10 Lower lip much wider than its height; oblique rows of scales from lateral line to dorsal origin 8–10; dorsal fin rays 10–12; least caudal peduncle depth more than one-half length of dorsal fin base; no membranous connection between pelvic fins and body .... WHITE SUCKER, *Catostomus commersoni* (p. 538)



Lower lip almost as high as wide; oblique rows of scales from lateral line to dorsal origin 11–14; dorsal fin rays usually 13–15 (rarely 12 or 16); least caudal peduncle depth less than one-half the dorsal fin base; membranous connection between pelvic fins and body .... LARGESCALE SUCKER, *Catostomus macrocheilus* (p. 544)



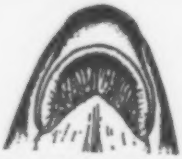
11 Caudal peduncle scales almost always 16, often 15, very rarely 13 or 12 (subgenus *Megapharynx*) 12

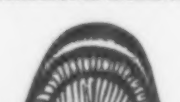
Caudal peduncle scales almost always 12 or 13, very rarely 15 or 16 (subgenus *Moxostoma*) 13

12 Maximum depth into body length to end of scales usually less than 3.5 times, snout length less than post-orbital length; scales across back just anterior to dorsal fin (excluding lateral line scales) 15 or 16; pharyngeal arch very heavy; lower pharyngeal teeth large, molariform, 4–6 on lower half of tooth row........ .... COPPER REDHORSE, *Moxostoma hubbsi* (p. 577)

Maximum depth into body length to end of scales usually about 4 times or more; snout length greater than post-orbital length; scales across back just anterior to dorsal fin (excluding lateral line scales) 12 or 13; pharyngeal arch light; lower pharyngeal teeth smaller, comblike, 12–30 on lower half of tooth row .... GREATER REDHORSE, *Moxostoma valenciennesi* (p. 584)

13 Maximum depth into body length to end of scales 3.5 times or less; plicae of lips with distinct transverse lines, lower lip thin .... SILVER REDHORSE, *Moxostoma anisurum* (p. 564)





Maximum depth into body length to end of scales about 4 times or more; no transverse lines crossing plicae of lips, lower lip thicker 14

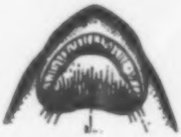
14 Origin of pelvic fins anterior to midpoint of base of the dorsal fin; lateral line scales usually 42–45, scale bases moderately to well darkened; caudal fin reddish in life; pharyngeal arch heavy and triangular; lower teeth large, molariform, increasing in size toward bottom, 6–9 on lower half of tooth row .... RIVER REDHORSE, *Moxostoma carinatum* (p. 567)

Origin of pelvic fins opposite the midpoint of the base of the dorsal fin; lower pharyngeal less heavy, not triangular; teeth compressed, comblike, and numerous 15

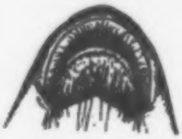
15 Eye diameter equal to about one-half the maximum width of the lips; nostrils above the tip of the maxillary .... BLACK REDHORSE, *Moxostoma duquesnei* (p. 571)

Eye diameter equal to two-thirds or more of the maximum width of the lips; nostrils behind the tip of the maxillary 16

16 Posterior edge of lower lips nearly a straight line; mouth small, lips not reaching maximum width of snout, mouth overhung by snout; head roundly pointed, 18.5–23.3% standard length .... SHORTHEAD REDHORSE, *Moxostoma macrolepidotum* (p. 579)

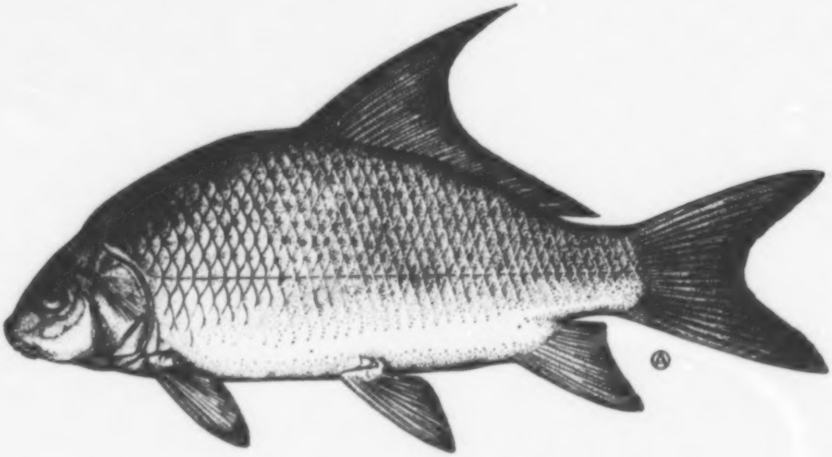


Posterior edge of lower lips a definite obtuse angle; head more flattened at front; mouth larger, lips nearly reaching maximum width of snout; mouth slightly overhung by snout .... GOLDEN REDHORSE, *Moxostoma erythrurum* (p. 574)

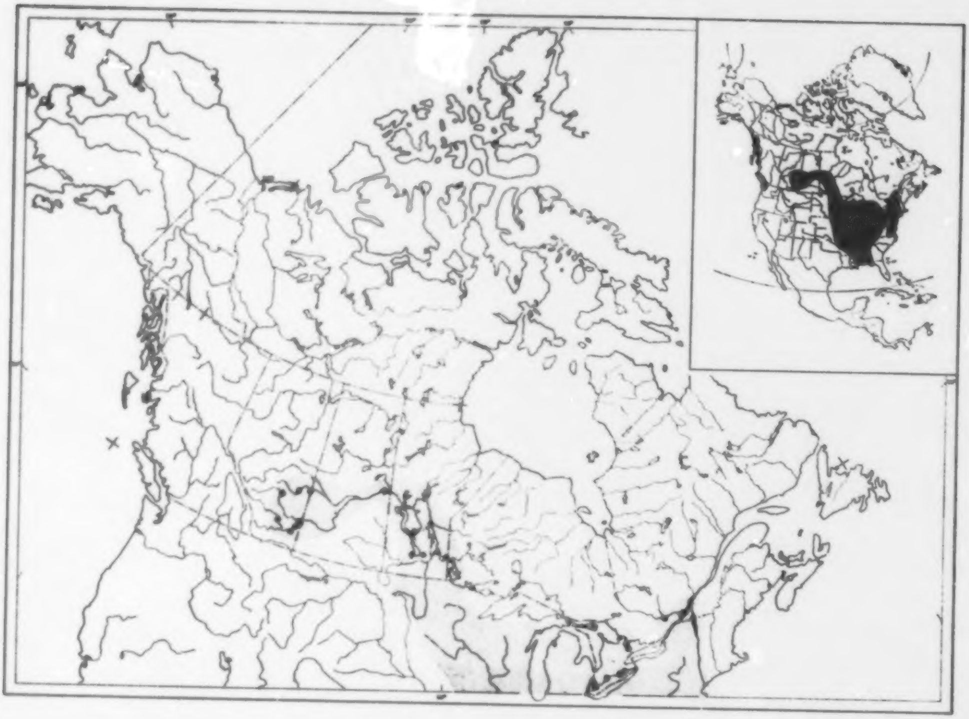


QUILLBACK

Carpiodes cyprinus (Lesueur)



Description A large, very deep-bodied, laterally compressed sucker, greatest depth of body at origin of dorsal fin 22.2–28.9% of total length, back highly arched; caudal peduncle laterally compressed, short and moderately deep, 9.0–11.9% of total length; individuals usually 10–15 inches (254–381 mm) in length. Head deep but rather short, about 16% of total length, and narrow; interorbital width 31.2–40.9% of head length, upper surface of head a steep angle; eyes forward of midpoint of head, moderately small, eye diameter about 16% of head length and approximately equal to snout length; skull with anterior and posterior fontanelle; snout short, but about 26–36% of head length, terminating in a rounded point; sucker mouth horizontal, ventral, and small, maxillary reaching anterior edge of orbit; lips with fine, well-marked transverse plicae, the halves of the lower lip meet in an acute angle; no teeth on jaws or roof of mouth, pharyngeal teeth very small, thin, compressed, forming a very fine comb, cutting edges rising to a point. Gill rakers 25–29, short, approximately 2 mm in length. Branchiostegal rays 3, 1 on epihyal, 2 on ceratohyal, paddle-shaped. Fins: dorsal 1, soft rayed, origin slightly ahead of midpoint of body, base very long, 25.5–30.4% of total length, dorsal edge deeply crescentric, anterior rays much produced, as much as 5 or 6 times longer than last rays, anterior height almost equal length of base, and about 28% of total length, 25–30 rays; caudal moderately long and wide, well forked, tips somewhat pointed, approximately 18 rays; anal moderately long, anterior height twice that of base length, pointed, and edge slightly crescentric, 7–9 rays, usually 7; pelvics abdominal, low, near midpoint of body, pointed, base wide with axillary process, 8–10 rays; pectorals low, only moderately wide, tips pointed, usually 15 rays. Scales cycloid, large, 35–41 in lateral series, exposed portion higher than long; lateral line at level of eye, complete and almost straight; intestine very long with 6–9 coiled loops. Vertebrae 38–40. According to Huntsman (1967) in southern populations males only bear nuptial tubercles as follows: absent from the top of the head, covering the sides of the head from the level of the top of the eye, the ventral area of the



head from the mouth to the anterior branchiostegals, on the first dorsal ray, pectoral rays 1–9, pelvic rays 1 and 2.

Colour The dorsal surface, head and upper sides are buff to light brown, the sides are a shiny silver and the ventral surface cream to white; all fins are transparent to dusky, the ventral fins lighter in colour than the dorsal fin.

Systematic notes The confusion which arose from the use of names such as *C. thompsoni*, *C. velifer*, and *C. forbesi* particularly for western populations was discussed in Hubbs (1930a) and in Bailey and Allum (1962).

Distribution The quillback is restricted to North America. It occurs in the east from the St. Lawrence River south along the coast to about the Roanoke River, Va. West of the mountains, it extends through New York south to Alabama, west to Oklahoma, north through the eastern parts of the states from Kansas to the Dakotas, west in Canada to central Alberta.

In Canada, it occurs in the east in the St. Lawrence–Richelieu River, Lake Champlain, Ottawa River to about the level of Ottawa, apparently absent from Lake Ontario, but present in Lake Huron and Georgian Bay. In the west it occurs from Lake of the Woods west through south and central Manitoba, west in the Saskatchewan River, almost to the headwaters of the South Saskatchewan River in Alberta. Not often seen but apparently more abundant in Lake Champlain and in the western area than in Ontario. Although known earlier from Manitoba and Alberta, it was first recorded from Saskatchewan in 1946 (Sprules and Doan 1947).

Biology Virtually nothing is known of the biology of this species in Canada, but some statistics are available in Minnesota for populations of this species in Lake of the Woods. Little information on its biology is available anywhere.

Quillback migrate to spawning areas, often in streams or overflow areas of bends of rivers or bays of lakes, in April and May where they randomly deposit eggs over sand or mud bottoms. No nest is built and no care given the young. In the south, young reach a length of 4 inches (102 mm) by the first fall. Quillback are 4–6 pounds in weight at sexual maturity. Range of total length at various ages in the Des Moines River, Iowa, was given by Vanicek (1961) as follows:

Age	TL	
	(inches)	*(mm)*
1	3.3- 6.1	84–152
2	5.2–10.7	132–272
3	7.4–13.2	188–335
4	7.0–14.2	178–361
5	8.7–13.6	221–345
6	14.7–15.1	373–384
7	13.3–17.3	338–439
8	16.4–18.1	417–460
9	–	–
10	16.8	427

See also Fish (1932) and Mansueti and Hardy (1967) for details and illustrations of early development of young.

Growth in Canada is doubtlessly slower than this. Trautman (1957) gave maximum size in Ohio as 24–26 inches (610–660 mm) length and 9–12 pounds. In Canada maximum size is probably 15–18 inches (381–457 mm) in length.

The habitat of the quillback ranges from the clear lacustrine waters of the Great Lakes to turbid river waters in the prairies.

The food is said to be immature insects, other invertebrates and organic material contained in bottom sediments. It is said to be a competitor for invertebrate food with the channel catfish where the two occur together.

The young are probably preyed on by a large variety of predatory fishes but the larger adults, especially in turbid environments, probably escape predation by other fishes.

Hoffman (1967) listed, under the names *Carpiodes cyprinus* and *C. thompsoni* the following parasites: Protozoa, *Myxosoma rotundum*; Cestoda, *Hypocaryopyllaeus paratarius*, *Spartoides wardi*; Nematoda, *Rhabdochona cascadilla* and *Camallanus ancylodirus*. Dechtiar in 1967 and 1968 described two new parasites from this species, a trematode, *Neodiscocotyle carpioditis* and an acanthocephalan, *Neoechinorhynchus carpiodi*.

Relation to man The quillback is of no particular importance to man. It is a commercial species wherever it is abundant, particularly in the Mississippi River. In Ontario, the catch is included in the statistics for suckers or for coarse fish. The flesh is white, flaky, sweet, and very tasty, particularly in the spring. Its suitability as a food fish is marred by the large number of bones which makes it hard to process (by machine or by hand) and to eat. Suckers of any kind, regardless of the actual quality of their flesh, have never been favoured by the Canadian consumer.

In the United States they are caught by anglers using doughballs as bait or by snagging them with bare hooks. There is no indication of any angling for them in Canada.

Nomenclature

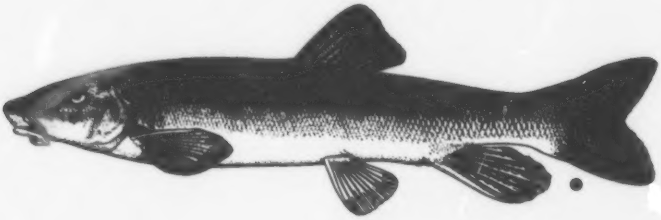
Catostomus Cyprinus — LeSueur 1817d: 91 (type locality Elk River and other tributaries of Chesapeake Bay)
Labeo cyprinus — Richardson 1836: 109
Carpiodes Thompsoni — Agassiz 1855: 76
Carpiodes Cyprinus — Small 1883: 38
Carpiodes velifer — Thompson 1898: 214
Catostomus cyprinus Thompson — Bean 1903b: 98
Carpiodes cyprinus cyprinus (LeSueur) — Hubbs and Lagler 1947: 46

Etymology *Carpiodes* — carp like; *cyprinus* — after the island of Cyprus from whence the carp was supposedly introduced into Europe. Both a reversal of the names of the carp *Cyprinus carpio*, names allude to its similarity to that species.

Common names Quillback, lake quillback, quillback carpsucker, eastern carpsucker, carpsucker, quillback sucker, long-finned sucker, broad mullet, mullet, carp, lake carp, white carp, silver carp, drum. French common name: *couette*.

LONGNOSE SUCKER

Catostomus catostomus (Forster)



Description An elongate, cylindrical, torpedo-shaped body, almost round in cross section; not deep, greatest depth between paired fins, 14.2–18.3% of total length; caudal peduncle only moderately long and deep, depth 6.4–8.8% of total length; usually 12–14 inches (305–356 mm) in length. Head moderately long, about 20% of total length, moderately broad, interorbital width 35.2–46.1% of head length, rounded on top, naked; eye small, diameter 38.4–66.6% of snout length, high and beyond midpoint of head; snout long, 38.4–48.2% of head length, bulbous, ending in a rounded point, dorsal surface sometimes concave over mouth; mouth ventral, well behind tip of snout, protrusible, suctorial, moderately small, gape extending no more than to midpoint of snout; lips large with coarse, long, oval papillae; no teeth in mouth, pharyngeal teeth in single row, comblike but ascending length, 37–45 + 35–46 according to McPhail and Lindsey (1970). Gill rakers short and fleshy, 23–30. Branchiostegal rays 3. Fins: dorsal 1, soft rayed, origin ahead of midpoint of body, height slightly greater than base, base 9.4–12.0% of total length, edge somewhat emarginate, 9–11 principal rays; caudal only moderately long, moderately forked, tips rounded points; anal long, its height about 2.5 times length of base, tip pointed to rounded, rays prominent, 7 principal rays; pelvics abdominal, only moderate in length, base fairly wide (fin length twice base length), axillary process present but small, fleshy stays at base (noticeable in large individuals only), fin square to rounded, 9–11 prominent rays; pectorals low, horizontal, somewhat stiff, 16–18 rays, tips broadly pointed. Scales small, cycloid, crowded towards head, larger on caudal peduncle, 99–108 in lateral series in material examined, apparently to 120 in total, scales not visible to naked eye on peduncle of individuals less than 3 inches (76 mm) in length; lateral line complete, inconspicuous, almost straight and at midpoint of body. Peritoneum variable, silver to shiny black; intestine long, undifferentiated, 2 or 3 coils, stomach scarcely differentiated; no pyloric caeca. Vertebrae, including Weberian ossicles, 45–47.

Nuptial tubercles developed, on breeding males only, on lower lobe of caudal fin, anal fin, and head.

Colour The adults are generally dark, with strong countershading. The back, upper sides, and head to below the eyes, are dark olive with brassy reflections, or grey to almost black, the lower sides and the ventral surface of head and body are cream to white. At breeding time, the males and females have a broad, horizontal, midlateral band of vivid rose or wine which continues on to the snout, that of the male is more vivid. The upper surface of the body of males is almost black, that of females green-gold to coppery brown. The undersurface of the head including the mouth, is often yellow to orange. The ventral surface of the body is white to pink. The unpaired fins are dusky to dark, sometimes edged in pale red, the paired fins amber, suffused with pale pink.

The young are dark in colour, somewhat mottled on the back.

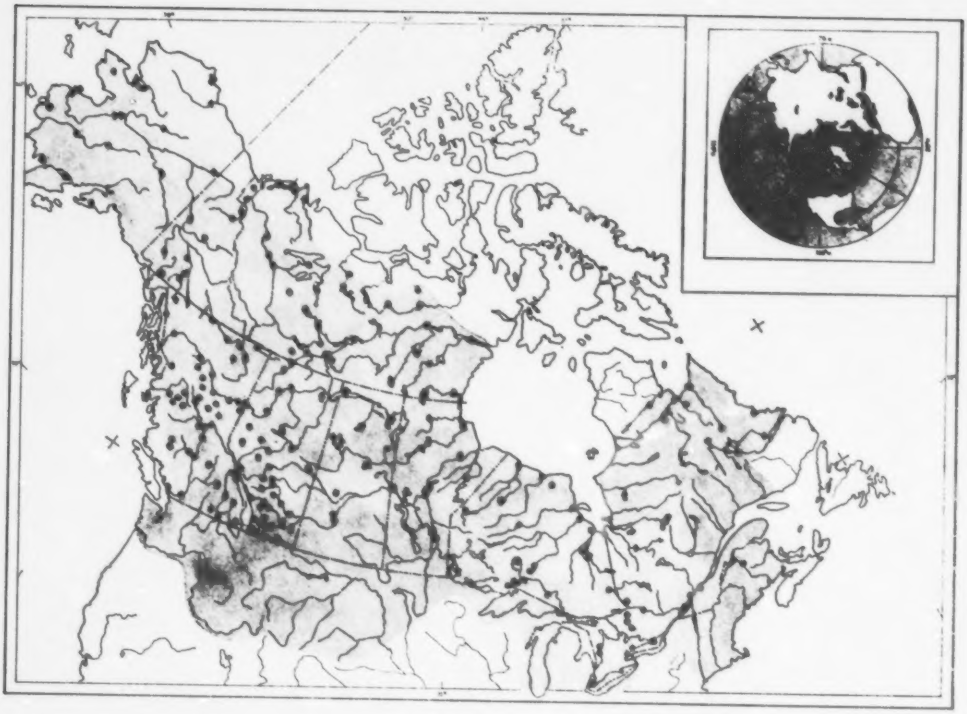
Systematic notes This species, like the white sucker, is extremely variable, and was once thought to be several subspecies such as *retropinnis*, *griseus*, *richardsoni*, and *rostratus*. It is known in various places over its range in a semidistinct dwarf form, known in the east as *C. c. nannomyzon*, as *C. c. lacustris* in Jasper Park, and as *C. c. pocatello* in the western United States. McPhail and Lindsey (1970) spoke of two morphological forms in the northwest, those in the Bering Sea drainages with 23–29 (usually 25 or 26) gill rakers and those in eastern Canada and waters as far west as the Mackenzie River with 25–30 (usually 27 or 28) gill rakers. Populations in New Brunswick appear to differ from those in Ontario but this may be simply a reflection of the great variability over the entire range.

Distribution This is the only North American sucker which occurs in Asia as well. It is present in Arctic drainages of Siberia from the Yana, Kolyma and Anadyr rivers. In North America it occurs from central Quebec and western Labrador south to Maryland, west through Pennsylvania, north to Minnesota, absent from all but the upper Mississippi in Minnesota, to northern Colorado, north through Washington to Alaska.

In Canada, especially in the northwest, the longnose sucker is more general in occurrence than even the lake trout and the northern pike. It occurs from New Brunswick, Quebec north to Povungnituk, and central Ungava, western Labrador, generally throughout the rest of the provinces and territories other than northeastern Keewatin and extreme southwestern British Columbia. Not present in the Arctic islands or Newfoundland.

Biology The biology of this species in Canada is not so well documented as that of the white sucker but more information is available than for many other species. Useful summaries of information were written by Harris (1962) and Geen et al. (1966) and much of the following is taken from these two accounts.

Longnose suckers spawn in the spring, in streams where available, but otherwise in shallow areas of lakes. They enter spawning streams as soon as stream temperature exceeds 41° F (5° C) usually in mid-April to mid-May. The spawning run of this sucker begins and reaches a peak several days before the run of white suckers in the same stream. Longnose suckers move upstream between noon and midnight with the greatest number moving in the evening hours. Spawning often takes place in stream water 6–11 inches (152–279 mm) deep, with a current



from 30 to 45 cm per second and a bottom of gravel 50–100 mm in diameter. During spawning, which takes place during the period 6 AM to 9 PM, a female moves from quiet water near shore into a group of males near stream centre. Two to four males crowd around one female, clasping her with, or beating against her with, their anal fins, and thrash about. Spawning act lasts for 3–5 seconds and occurs as often as 6–40 times per hour. After depositing eggs, the sexes separate and return to their previous stream positions. No nest is built, the white, adhesive, demersal eggs are laid in small numbers and adhere to the gravel and substrate. Ripe eggs in the ovary are yellow, 2.8–3.0 mm in diameter, and invested with a thin gelatinous coating. Egg number ranges from 17,000 to 60,000 per female. As early as 5 days after the migration begins, some adults are leaving the spawning streams, so the spawning period is of short duration. Mortality of adults during the spawning run is probably no more than 10–25%. Eggs hatch experimentally in 8 days at 59° F (15° C) and 11 days at 50° F (10° C), but hatching probably takes 2 weeks in nature at the prevalent stream temperatures. The young remain in the gravel 1–2 weeks before emerging and in June, or about 1 month after spawners first appear, fry are moving down to the lake. At this time, they are 10–12 mm in length. Fry in Great Slave Lake in 1950 had grown to a maximum of 80 mm by the end of August. Growth rate in older longnose suckers was calculated at approximately 15–20 mm per year. Most published accounts of ages and age–length relations are based on ages estimated from scales. On the bases of a critique by Beamish and Harvey (1969) of aging by scales in white suckers, these published ages may be less than actual by as much as 5 years. Published age–length relations for various Canadian populations are as follows:

	Mean FL					
Age	N Sask. R., Sask. (Reed 1962)		Gt. Slave L., N.W.T. (northern part) (Harris 1962)		Pyramid L., Alta. (Rawson & Elsey 1950)	
	(inches)	*(mm)*	*(inches)*	*(mm)*	*(inches)*	*(mm)*
1	–	–	–	–	2.0	51
2	–	–	6.0	152	3.3	84
3	12.7	323	6.7	170	4.2	107
4	15.1	384	10.0	253	5.2	132
5	16.8	427	11.4	290	6.0	152
6	17.3	439	12.3	314	7.0	178
7	–	–	13.0	330	8.0	203
8	–	–	14.6	372	8.8	224
9	–	–	15.8	403	9.6	244
10	–	–	17.0	433	10.4	264
12	–	–	19.6	499	12.4	315
15	–	–	21.5	547	–	–
19	–	–	25.2	642	–	–

These figures illustrate the extreme variability in growth from place to place. Size at the same estimated age can be as much as 40 mm greater in a population in southern Great Slave Lake than one in northern Great Slave Lake. The Pyramid Lake population shown was the one described by Bajkov (1927) as a dwarf, under the name *C. c. lacustris*, saying they grew to no more than 4.5 inches (114 mm). Specimens up to 16 inches (406 mm) were found later and no evidence was found to separate this population as a subspecies (Rawson and Elsey 1950). Lacking more reliable ages by pectoral fin sections, it is impossible to assess how much of this variation is attributable to error in aging. Some reports stated there is no difference in growth rate between males and females taken in the lake; others, that in the spawning run, males are always smaller than females. Females live longer and achieve a greater maximum size.

Age at first sexual maturity is equally variable and equally subject to the aging error. In British Columbia, spawners were 5.1–15.7 inches (130–400 mm) fork length, mostly 10–12 years of age. First spawning was estimated to occur at 5–7 years of age. In Great Slave Lake, no spawners younger than an estimated 9 years of age were seen. Longnose suckers live to spawn more than once and in southern areas in successive years; 20–50% of them twice, 10–30% a third time, and smaller numbers through to a sixth time.

The individual often quoted as the North American size record is from Great Slave Lake, 25.2 inches (642 mm) fork length, 7.3 pounds in weight, and estimated to be 19 years old (Keleher 1961). They may, however, be as old as 22–24 years of age.

The longnose sucker is the most successful and widespread cypriniform in the north occurring almost everywhere in clear, cold water in moderately large numbers. It occurs in the south more sporadically, in more restricted environments (the deeper areas only of lakes), and in fewer numbers. Generally restricted to freshwater lake bottoms or tributary streams, it is, however, reported from brackish water about the mouths of arctic streams. It is reported from as deep as 600 feet in Lake Superior but not below 80 feet in Great Slave Lake. The latter might be the maximum depth at which nets were set rather than a true depth stratification of the longnose sucker.

Upper lethal temperature was calculated as 79.8° F (26.5° C) when acclimated at 57.2° F (14° C), and as 80.6° F (27° C) when acclimated at 52.7° F (11.5° C) (Black 1953).

The food of this sucker is variable from place to place, season to season, and by size. It is, however, totally invertebrates taken from the bottom and no vertebrates have been reported. A typical food list in order of frequency of occurrence is as follows: Amphipods (*Hyalella*), Trichoptera, chironomid larvae and pupae, Ephemeroptera, ostracods, gastropods, Coleoptera, pelecypods, copepods (*Cyclops*), cladocerans (*Bosmina*), and plants. There are older records of the food being largely algae. As with the white sucker, this species would appear to be largely erroneously considered a serious egg predator of more valuable fish. However, one record indicated that longnose suckers 14–16 inches (356–406 mm) in length had 0–98 brook trout eggs in the gut. It was known that these eggs had been exposed by superimposition of nests on limited spawning grounds and may have been dead when eaten (Stenton 1951).

The young of this species probably fall prey to a wide variety of predaceous fishes and fish-eating birds. Even larger longnose suckers are taken by northern pike. Adults in the spawning streams are probably taken by bears, other mammals, and by osprey and eagles.

As bottom feeders, longnose suckers are competitors for food with all other bottom feeders except those from whom they are spatially separated in the deeper water.

In Saskatchewan the fluke *Metorchis conjunctis* infects this species and accumulates by the thousands in the livers of dogs fed raw suckers. There is a record of the death of 10 sleigh dogs in northern Saskatchewan as a result of this parasite (Rawson 1960).

Hoffman (1967) listed the parasites of this species as follows: Trematoda (10), Cestoda (7), Nematoda (4), Acanthocephala (9), leeches (1), Crustacea (1). Parasites were also given in Bangham (1955) and Bangham (1941).

Dechtiar (1969) described a new monogenetic trematode *Pellucidhaptor catostomi* from the nasal cavity of this species.

Relation to man The utilization of this fish as food by native peoples in northern Canada ranges from nil to extensive. It is used everywhere as food for dogs, but even they prefer lake whitefish. The flesh is firm, white, flaky, and sweet. Other than the numerous bones, the flesh is edible and more palatable than that of white suckers. Those taken in the Great Lakes are often marketed as frozen fillets, called "mullet," and said to be received with some favour. This species made up 7% of the summer commercial catch in Great Slave Lake in 1945. It is entered in the commercial records in Ontario with all other suckers, which in 1966 totaled slightly more than 1.3 million pounds, valued at $22,456.

Nomenclature

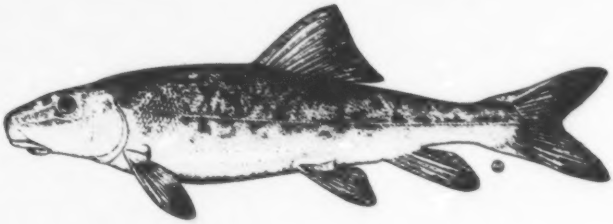
Cyprinus Catostomus	— Forster 1773: 158 (type locality tributaries of Hudson Bay)
Catastomus Forsterianus	— Richardson 1823: 720
Cyprinus (Catastomus) Forsterianus (Rich.)	— Richardson 1836: 116
Cyprinus (Catastomus) reticulatus (Cuvier)	— Richardson 1836: 303
Catostomus aurora	— Agassiz 1850: 360
Catostomus communis	— Fortin 1864: 64
Cyprinus catostomus	— Fortin 1866: 72
Catostomus forsterianus	— Fortin 1866: 72
Catostomus hudsonius	— Günther 1868: 13
Catostomus longirostris	— Adams 1873: 253
Catostomus griseus (Girard)	— Eigenmann 1895: 108
Catostomus catostomus (Forster)	— Jordan and Evermann 1896–1900: 176
Catostomus catostomus lacustris	— Bajkov 1927: 380
Catostomus c. catostomus (Forster)	— Bangham 1955: 187
Catostomus catostomus rostratus (Tilesius)	— Walters 1955: 295

Etymology *Catostomus* — inferior mouth alluding to the ventral position of the mouth.

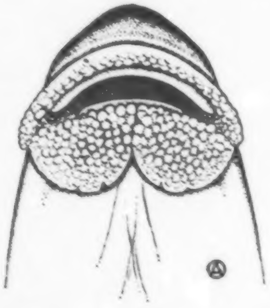
Common names Longnose sucker, sturgeon sucker, northern sucker, finescale sucker, red sucker, red-sided sucker, black sucker. French common name: *meunier rouge*.

BRIDGELIP SUCKER

Catostomus columbianus (Eigenmann and Eigenmann)



Description A very rounded, torpedo-shaped fish, usually 8–12 inches (203–305 mm) in length. Body cylindrical, not laterally compressed, greatest depth ahead of origin of dorsal fin, 18.5–19.8% of total length; caudal peduncle shallow, depth 5.7–7.2% of total length. Head moderately long, about 20% of total length, wide, interorbital width 40.0–45.8% of head length, not deep; eye high on head at midlength and moderately large, diameter 38.4–45.4% of snout length; snout long, 47.6–50.0% of head length, rounded; mouth ventral, little overhung by snout, protrusible and suctorial, gape reaching to nostril, cartilagineous edge of jaws visible in open mouth; lips thick, papillae large, round, lobes of lower lip rounded, not completely cleft, 2–5 rows of papillae crossing base, papillae on anterior edge of upper lip, sometimes a slight notch at lateral point of connection of upper and lower lips; no teeth in mouth, pharyngeal teeth in single row, flat, comblike. Gill rakers short and fleshy, about 24–42 + 34–55 (Smith 1966). Branchiostegal rays 3. Fins: dorsal 1, soft rayed, base 13.0–14.6% of total length, more than twice depth of caudal peduncle, height greater than base, edge only slightly emarginate, rays 11 or 12 in material examined, but 11–14 over whole range (Carl et al. 1967); caudal rather long, deeply forked, tips rounded points; anal not markedly long, length about equal to height of dorsal, tip a rounded point, 7 rays; pelvics abdominal, low, origin at midpoint of dorsal fin, wide base with fleshy pad, but no axillary process, and obvious membranous stays, 10 or 11 rays, tip a rounded point; pectoral low, long, pointed, 17 rays. Scales cycloid, small, crowded anteriorly, larger on caudal peduncle, lateral line scales 87–99 in material examined, 88–124 over British Columbia (Carl et al. 1967); lateral line at midpoint of body, pale, complete but often with breaks and branches. Peritoneum black; intestine long, 6–14 loops anterior to liver, little differentiated; no pyloric caeca, swim bladder of 2 chambers, not reduced, reaches at least to origin of pelvic fins. Vertebrae, including Weberian ossicles, 43–51.



Nuptial tubercles on anal fin, lower lobe of caudal fin, and on scales of posterior half of the body on males.

Colour Back and top of head dark brown to olive, upper sides often somewhat mottled and paler brown, lower sides, head below eye, and ventral surface white to pale yellow. Lateral line prominent near head, and paler than background. Breeding males with prominent, orange lateral band. Young with black peritoneum obvious in abdominal region, and often with 3 dark lateral blotches.

Systematic notes Miller and Miller (1948) discovered that *Pantosteus columbianus* of Eigenmann and Eigenmann (1893a) and *Catostomus syncheilus* Hubbs and Schultz (1932), applied, in part, to the same species, that it was not a synonym of *Pantosteus jordani* (= *C. platyrhynchus*) as suggested by Eigenmann in 1895, and that it should not be put in the genus *Pantosteus* but in the genus *Catostomus*. The discussion concerning *Pantosteus* versus *Catostomus* was given by Smith (1966). Smith recognized 3 subspecies *C. c. columbianus*, *C. c. palouseanus*, *C. c. hubbsi*.

Hybrids between the bridgelip sucker and the largescale sucker are known.

Distribution Restricted to the fresh waters of northwestern North America. It occurs in the Columbia River drainage from British Columbia to Nevada, below the great falls of the Snake River, from Idaho west to at least central Oregon and Washington, and north in the Fraser River to central British Columbia (*see* Smith 1966).

In Canada, it is limited to British Columbia where it occurs in Erie and Lower Arrow lakes, East Kootenay District (Columbia River), in Osoyoos Lake and the Similkameen River, south-central British Columbia (Columbia River), Nicola Lake, North Thompson River, Quesnel River (Fraser River), and tributaries of the Fraser River from Australian Creek to Prince George, including Wright Creek, Salmon River, Beaverley Creek and the West Road River (Carl et al. 1967).

Biology Virtually nothing is known of the biology of this species in Canada or elsewhere. It probably spawns in late spring in British Columbia as ripe females were taken on June 9 near Prince George, but earlier to the south. Eggs are as large as 2.8 mm in diameter. Young were 7 mm on July 10 in Idaho and 2.5–3.1 inches (40–80 mm) by the end of the first summer. Sexual maturity is first reached when individuals are about 5 inches (127 mm) in length. Adult maximum size was 10 inches (250 mm), according to Smith, and to 15 inches (381 mm) according to Carl et al.

The habitat of this species is usually colder water of small, swift rivers with gravel to rocky bottoms, but it is also found in rivers where current is more moderate and the bottom of sand and mud. It is only infrequently found in lakes.

Carl et al. noted that the cartilagineous edges of the jaws and the black peritoneum of this species suggested its food might be obtained by scraping algae from rocks. The food would include invertebrates taken while feeding on the bottom.

This species occurs in an area where large predaceous fishes are not abundant After it reaches adult size it may escape predation by other fishes. It may be preyed on by mammals and birds.

The parasites of this species were listed by Hoffman (1967) as follows: Trematoda (1), Cestoda (1), Acanthocephala (4), Crustacea (1).

Relation to man This species is of very little, if any, direct or indirect relation to man. It is edible and may have constituted food for native peoples and their dogs but it is not eaten today. It may constitute food, when small, for economically important salmonids. It may, in turn, compete with such salmonids for food. It is not presently a fish pursued by anglers.

Nomenclature

Pantosteus columbianus — Eigenmann and Eigenmann 1893a: 151 (type locality, Boise River, Caldwell, Ore. (= Idaho))

Pantosteus jordani Evermann — Eigenmann 1895: 107

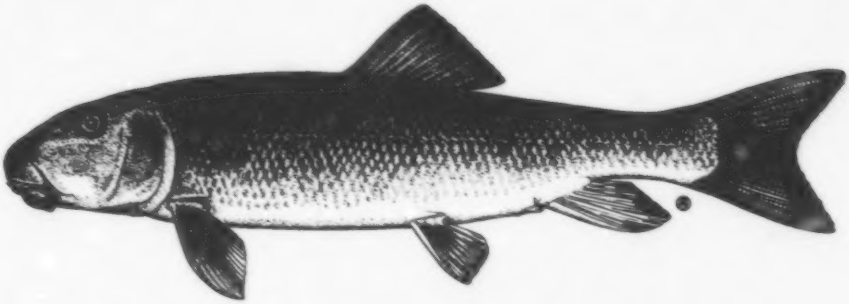
Catostomus syncheilus — Hubbs and Schultz 1932: 6
Catostomus columbianus
(Eigenmann and Eigenmann) — Miller and Miller 1948: 177

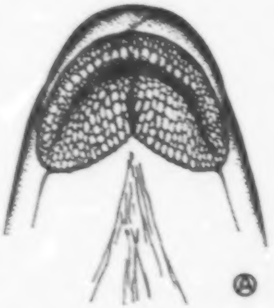
Etymology *Catostomus* — inferior mouth; *columbianus* — of the Columbia River.

Common names Bridgelip sucker, Columbia small scaled sucker. French common name: *meunier de l'ouest.*

WHITE SUCKER

Catostomus commersoni (Lacépède)





Description A robust, cylindrical, torpedo-shaped fish, usually 12–20 inches (305–508 mm) in length; round to oval in cross section forward, little compressed laterally, greatest depth at origin of dorsal fin 14.1–20.0% of total length; caudal peduncle moderately long and slender, depth 6.5–8.6% of total length. Head moderately long, about 20% of total length, naked, bluntly pointed, rounded on top, moderately wide, interorbital width 35.2–49.5% of head length; eye small, 41.3–66.6% of snout length, high but at centre of head length; snout rounded, sometimes square, fleshy, overhanging upper lip, 35.7–50.0% of head length; mouth ventral (terminal until 2 mm total length), toothless, suctorial, moderately small, maxillary extending half the snout length; lips fleshy, thick, papillate, papillae small and oval; pharyngeal teeth in single row, comblike (*see* p. 25), 40–42+39–43 according to McPhail and Lindsey (1970). Gill rakers approximately 20–23, short to long, somewhat knobbed, on both surfaces of the arch. Branchiostegal rays 3. Fins: dorsal 1, soft rayed, almost at midpoint of total length, origin ahead of pelvics, base short 10.7–15.0% of total length, slightly emarginate, 10–13 principal rays; caudal deeply forked, tips roundly pointed, usually 18 rays; anal long, height at least 2 times base, more or less pointed, 6–8 large, principal rays; pelvics abdominal, low, under middle of dorsal, short, square, with moderately broad base, small axillary process, 10 or 11 rays; pectorals low, long, almost equal to head length, pointed, 16–18 prominent rays. Scales moderately small, larger on peduncle than near operculum, 53–74 in lateral series, scales on peduncle visible to naked eye on 3-inch (76-mm) fish; lateral line complete, straight, at midpoint of body. Peritoneum pale or lightly speckled; intestine long, about 4 or 5 coils, simple, no area differentiated as stomach; no pyloric caeca; swim bladder of 2 chambers. Vertebrae 45–48, including Weberian ossicles.

Nuptial tubercles on males, well developed on rays of anal fin, lower lobe of caudal fin and on some caudal peduncle scales, minute tubercles on undersurface of head between the bases of the pectoral fins and the posterior margin of the operculum. There is a smaller number of poorly defined tubercles on some females. External characters for sexing white suckers were described by Spoor (1935).

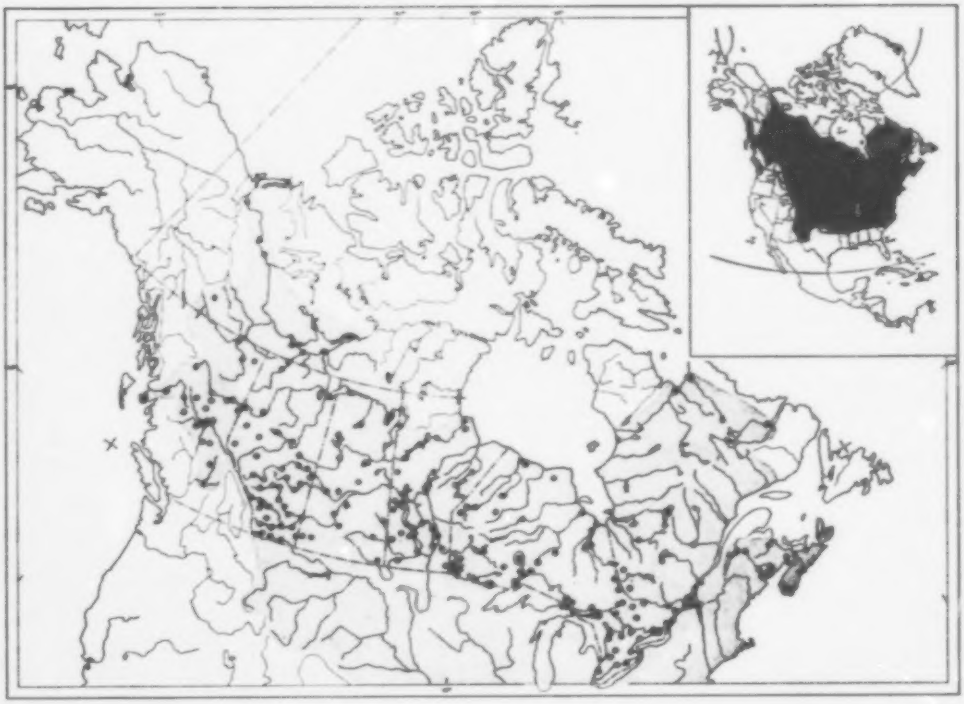
Colour In adults, the back, top of head, upper sides, and sides of head to below the eye are grey, coppery brown through brown, to almost black, lower sides and ventral surface of head and body cream to white; anal fin whitish, other fins dusky. Young 2–6 inches (51–152 mm) in length usually with 3 large, prominent, black spots on sides of body. In spawning individuals, the body is more golden in colour and the dark of the upper parts deeper and more intense. Males east of the Rocky Mountains and south of the Territories have a pronounced rose to nearly scarlet, wide, lateral band. In Saskatchewan, this is replaced by a pale, cream-coloured band and no band was noticed west or north of the mountains. In Ontario, this band varies in intensity from population to population and is often almost black in colour.

Systematic notes The white sucker seems to be a rather plastic animal and characters vary from area to area. There would appear to be a very slight north–south cline in some meristics and body proportions but many of these are effected by differing growth rates. Differences in general appearance, counts, and a tendency to develop dwarf populations, led to many separate names for different populations, including *teres*, *communis*, *flexuosus*, *reticulatus*, *gracilis*, *pallidus*, *chloropteron*, *commersoni suckleyi*, and *commersonnii utawana* (McPhail and Lindsey 1970). The possibility that there were, in the past, three geographically separated forms, from eastern, Plains, and Hudson Bay drainages, has been suggested by Metcalfe (1966) on the basis of body thickness, eye size, scale count, and number of lip papillae.

Kendall (1909) interpreted Low's (1896) *C. Forsterianus* Richardson, as *C. commersoni*, and Low's *C. longirostris*, LeSueur, as *C. catostomus*. Backus (1957) felt the reverse was true. Both names used by Low are usually considered synonyms of *C. catostomus*. On the basis of spawning time given by Low (*C. Forsterianus* 2 weeks later than *C. longirostris*) it would seem that Kendall's interpretation was correct.

Distribution Restricted to North America. Occurs from central Ungava, Labrador, Nova Scotia, south near the coast to western Georgia, extreme north of the Gulf states to northern Oklahoma, north through the eastern portions of the states from Colorado to Montana, through Alberta and British Columbia to the Mackenzie River delta.

In Canada, it is generally distributed from



central Ungava, Labrador, sporadically in Nova Scotia, generally in New Brunswick, in Quebec north only to near Fort Chimo where it is uncommon, generally distributed in southern Quebec and over all the provinces west to Alberta, north-central British Columbia (upper Fraser, Skeena, and Peace rivers), southeastern Yukon Territory, and across the Northwest Territories, at the level of the north shore of Great Slave Lake or within the tree line, from Hudson Bay to the Mackenzie River. Downstream in the Mackenzie River to the delta.

Biology As a result of the abundance and widespread distribution of this species, its capture during studies of economically important fishes, and its minor importance as a commercial fish, much is known of its biology in Canada. Special studies of its biology were made by Campbell (1935) and Geen et al. (1966) from which the following is largely taken.

White suckers spawn in the spring, usually from early May to early June. Adults usually migrate from lakes into gravelly streams when stream temperatures first reach 50° F (10° C), but they are also known to spawn on lake margins, or quiet areas in the mouths of blocked streams. Spawning sites are usually in shallow water with a gravel bottom but they may spawn even in rapids. Adults home to certain spawning streams. Thousands may ascend a suitable stream, as many as 500 passing a point in 5 minutes. In certain lakes a segment of the population spawns in the lake and another in tributary streams. At times white suckers move into tributaries at spawning time but actually spawn in the lake rather than in the stream. The bulk of spawning at one Ontario locality took place at dusk and dawn. Spawning did take place during daylight hours but to a much more limited extent and usually only at the peak of spawning activity.

On the spawning grounds two to four

males often crowd around one female, pressing her with their tuberculate fins during irregularly spaced spawning acts lasting 3–4 seconds, and occurring 6–40 times an hour. Egg number in Minnesota varied from 36,000 to 139,000 in females 7–20 inches (178–510 mm) total length. The usual number is probably 20,000–50,000. In Waskesiu Lake, Sask., there were approximately 11,160 eggs per pound of body weight. Eggs are yellow. No nest is built, eggs are scattered, they adhere to the gravel or drift downstream and adhere to the substrate in quieter areas. Adults begin moving off the spawning grounds to the lake 10–14 days after spawning begins. Eggs hatch in about 2 weeks (8–11 days at 50°–59° F or 10°–15° C in the laboratory), the young remain in the gravel 1–2 weeks and fry start to migrate to the lake about a month after spawning begins. They are at this time 12–17 mm in length. There may be as little as 3% survival from egg to migrant fry.

For details and illustrations of egg and early development of the young, *see* Fish (1932) and Mansueti and Hardy (1967).

Growth of young white suckers is extremely variable from lake to lake. Daily increment in Waskesiu Lake was calculated at 0.1 mm and 0.4 mm in early and late June. Fry grew from an average length of 9.25 mm on May 26 to 55.2 mm on September 5. Growth in length in subsequent years is slower, variable from place to place, probably never more than 10–20 mm per year, and difficult to interpret. Growth may cease after sexual maturity is attained. Records from the literature are now suspect as most ages have been calculated from scales, and Beamish and Harvey (1969) stated that, whereas pectoral fin ray sections provide a reliable age interpretation over the whole life, ages by scales are reliable only to the fifth year. Over age 8, ages determined from scales could be as much as 5 years in error. Some published age–length relations for Canadian populations, including a recent fin ray determination in George Lake, Ont., are shown below.

Growth rates are extremely variable from one location to another but these figures demonstrate the difficulty, expressed by most authors, in aging white suckers by their scales. Females appear universally to grow faster than males, achieve larger sizes, and to live longer. Age at first attainment of sexual maturity varies over the range from 5 to 8 years (usually 3–4 years in Ontario), with males spawning first a year earlier than females. Spawning mortality in the north and west is usually 15–20% but is lower in the east. At least 20% spawn a second time, 10% a third time, and a few individuals

Age	Gibson L., N.B. Smith (1952) (age determination by scales)		Lake of the Woods, Ont. Chambers (1963) (age determination by scales)		Waskesiu L., Sask. Campbell (1935) (age determination by scales)		George L., Ont. Beamish (1970) (age determination by pectoral fin rays)	
	Mean FL		Mean FL		FL		Mean FL	
	(inches)	*(mm)*	*(inches)*	*(mm)*	*(inches)*	*(mm)*	*(inches)*	*(mm)*
1	–	–	–	–	–	–	7.0	179
2	–	–	8.8	224	–	–	10.8	274
3	–	–	11.2	284	3.9–5.5	100–140	13.2	336
4	8.5	217	11.9	302	5.9–7.8	150–200	15.2	387
5	9.3	236	15.1	384	8.2–10.2	210–260	16.7	424
6	10.0	254	15.6	396	10.6–13.0	270–330	17.8	452
7	10.6	269	16.9	429	13.4–15.3	340–390	18.6	472
8	11.2	284	17.4	442	15.7–17.3	400–440	19.1	487
9	–	–	18.4	467	17.7–19.7	450–500	19.6	499
10	–	–	19.3	490	–	–	20.0	509
11	–	–	19.8	503	–	–	20.3	517
12	–	–	20.7	526	–	–	20.6	524
13	–	–	20.9	531	–	–	20.8	529
14	–	–	22.8	579	–	–	21.0	533
15	–	–	–	–	–	–	21.1	536

spawn four or more times. Campbell (1935) gave weight at ages 4, 6, and 9 as 3 ounces, 1.1 pounds, and 4.3 pounds. Maximum size records are rarely maintained for other than sport fishes but Keleher (1961) quoted a 6.9-pound fish from East Twin Lake, Conn., in 1939, and Chambers (1963) listed one of 7 pounds and 22.8 inches (579 mm) fork length, from Lake of the Woods, Ont. McPhail and Lindsey (1970) gave maximum length as 25 inches (635 mm). Maximum age would appear to be about 17 years.

White suckers are usually fish of warmer, shallow lakes or warm, shallow bays, and tributary rivers of larger lakes. They are usually taken from the top 20–30 feet of lakes but have been recorded below 151 feet in Great Slave Lake. In addition to spawning migrations, movements, other than a general tendency to move offshore with increase in age, are random, probably in response to temperature. White suckers are moderately active during the daytime but active feeding is usually restricted to near sunrise and sunset when they move into shallower water.

In Waskesiu Lake, the young were associated with the young of spottail shiner, blacknose shiner, yellow perch, and sticklebacks. The larger white suckers were taken with cisco, lake whitefish, northern pike, longnose sucker, yellow perch, walleye, and burbot.

For a detailed study of the food of the young by size and season *see* Bigelow (1923).

The fry at about 12 mm length begin feeding near the surface on plankton and other small invertebrates. At 16–18 mm, the period when the mouth moves from terminal to ventral, there is a shift to bottom feeding. There is a shift in the type of invertebrate food consumed with increasing size, and season. Campbell (1935) cited the range of percentage composition of the gut content of individual white suckers 4.6–9.6 inches (118–245 mm) fork length, over the period June to September as: Chironomidae 5–90%, Trichoptera 2–70%, Mollusca 5–85%, Entomostraca 5–98%, *Chaoborus* 50% (one individual). In total, chironomid larvae and pupae constituted 48% of the food taken and molluscs were next in importance. In Ontario, cladocerans constitute 60–90% of the food of many individuals in summer, the number in a single specimen is sometimes in the tens of thousands.

When less than 12 inches (305 mm) in length, white suckers which are often very abundant in warm lakes, constitute a major food item of a wide variety of predatory fishes such as northern pike, muskellunge, basses, walleye, and burbot. The smaller ones are eaten by predaceous birds; the fry are at times gorged on by Atlantic salmon and brook trout, and spawners in streams fall prey to bears and other mammals. Sea lampreys attack white suckers, particularly when the number of lake trout available is low, and have seriously reduced the number of larger white suckers in South Bay, Lake Huron.

They are bottom feeders, but do not apparently constitute serious competition for other browsing, shallow-water, bottom feeders such as trouts, basses, and sturgeons. They were often condemned as egg feeders and considered to do great damage on the spawning grounds of more desired species. The evidence for this is variable and nonconclusive. Ellis and Roe (1917) reported that egg predation by white suckers on logperch nests was as high as an average of 500 logperch eggs per sucker. Campbell (1935) found no eggs in 100 stomachs of white suckers taken on the lake whitefish spawning ground at spawning time. Stewart (1962) reported no eggs in a detailed study of the food of this species.

White suckers are subject to a wide variety of parasites and diseases, including bacterial furunculosis *(Aeromonas salmonicida)*. Hoffman (1967) listed the following parasites for this species over the whole of its range: Protozoa (11), Trematoda (28), Cestoda (16), Nematoda (14), Acanthocephala (13), leeches (4), Mollusca (1), Crustacea (7). Dechtiar (1969) described a new monogenetic trematode *Pellucidhaptor nasalis* from the nasal cavity of this species.

There are hybrids reported for the white sucker and the largescale sucker in Canada and the form referred to as *C. commersoni suckleyi* has been shown in the United States to hybridize with the mountain sucker, longnose sucker, and the bluehead sucker. There are puzzling, distinct, dwarf populations over most of its range. Often these dwarfs cohabit a lake with a normal population. Important studies of this form are those of Dence (1948) who worked with a population long known as *C. commersonnii utawana* (Mather), and of Beamish (1970).

Relation to man The flesh of the white sucker is edible and under many circumstances highly palatable. It is white, flaky, and sweet but somewhat bony. It makes good soups and chowders and if the upper muscle masses only are used almost all of the bones are avoided. When taken in cold water in the spring it is said to be tasty if fried in butter. It is as good as so-called prime fishes when hot-smoked. It is not, however, highly favoured commercially, forms only a small part of the commercial catch, and when marketed it and other suckers are usually called mullet. In 1921–1927 this species constituted 5% of the commercial catch in Waskesiu Lake, Sask. In 1966 the Ontario catch marketed as suckers (several species) was just over 1.3 million pounds with a value of almost $22,500. Much of it may have gone into pet food.

It is rarely angled for in Canada but anglers fish for it in the United States. Numbers of white suckers are netted for food during the spring spawning runs or when dipnetting smelt. It has a real and presently unutilized potential as a sport fish in Canada. They can be taken still fishing with a small hook and a variety of baits including doughballs. They will also strike small spinners and wet flies and provide good sport.

Considerable numbers of young suckers are sold annually, as bait, to anglers in the east, usually for basses, northern pike, and muskellunge, at a price of 75¢ to $1 a dozen. They are reared for bait in the United States (*see* Dobie et al. 1948) and reared and captured there and in Canada as the main food for hatchery rearing of game fishes.

Nomenclature

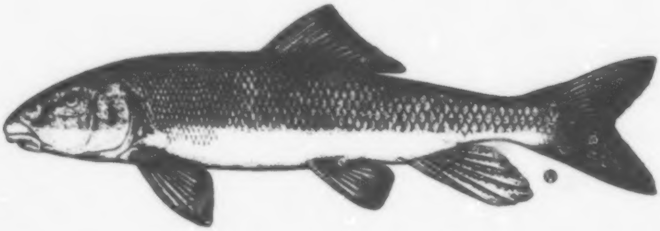
Cyprinus Commersonnii — La Cepède 1803: 503 (no type locality given)
Catastomus Hudsonius — Richardson 1823: 717
Cyprinus (Catastomus) Hudsonius (LeSueur) — Richardson 1836: 112
Cyprinus (Catastomus) reticulatus (Cuvier) — Richardson 1836: 303
Catostomus communis — Perley 1852: 192
Catastomus communis — Forelle 1857: 281
Catostomus Bostoniensis — Gill 1865: 261
Catostomus teres — Günther 1868: 15
Catostomus commersoni (Lacépède) — Eigenmann 1895: 108
Catostomus Forsterianus Richardson — Low 1896: 329
Catostomus commersoni Jordan — Cox 1896b: 64
Catostomus commersonii — Bean 1903b: 101
Catostomus richardsoni — Harper and Nichols 1919: 263
Catostomus commersonnii Lacépède — Hubbs 1926: 21
Catostomus commersonnii commersonnii (Lacépède) — Hubbs and Brown 1929: 20

Etymology *Catostomus* — inferior mouth; *commersoni* — after P. Commerson, an early French naturalist.

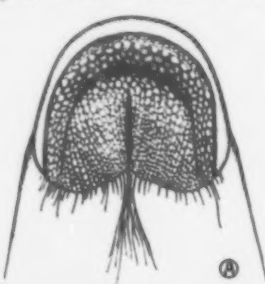
Common names White sucker, common sucker, common white sucker, coarse scaled sucker, fine scaled sucker, eastern sucker, grey sucker, black sucker, sucker, mullet, black mullet, carp. French common name: *meunier noir*.

LARGESCALE SUCKER

Catostomus macrocheilus Girard

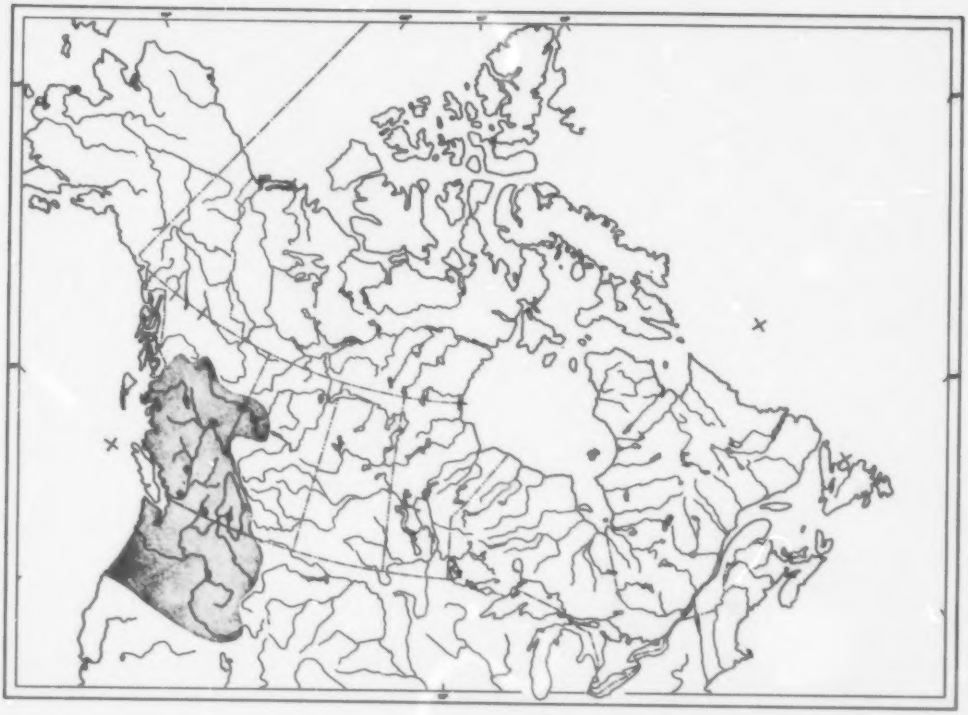


Description Body long, moderately deep, greatest depth at dorsal origin 15.0–18.7% of total length, more laterally compressed than longnose and white suckers, cross section of body at dorsal origin a deeper oval; caudal peduncle shallow, 5–7% of total length; body tapers rapidly behind dorsal fin; individuals usually 13–17 inches (330–432 mm) in length. Head moderately long, 20–23% of total length, deep, wide, interorbital width 35.0–42.5% of head length; eye high on head, a little ahead of centre of head, diameter 39.1–47.0% of snout length; snout bluntly rounded, with depression ahead of nostrils, moderately long, 35.0–47.5% of head length; mouth ventral but little, if at all, overhung by snout, protrusible, suctorial, moderately small, gape reaching only to nostrils, lips large, lower lip deeply incised, with coarse, oval papillae, no papillae crossing cleft at midline of lower lip, although sometimes 1 and rarely 2 irregular rows cross the base (Carl et al. 1967); no teeth in mouth; pharyngeal teeth in a single row, flattened, comblike, 43–46+43–48. Gill rakers short and fleshy, 25–37 (McPhail and Lindsey 1970). Branchiostegal rays 3. Fins: dorsal 1, soft rayed, large, a little ahead of midpoint of body, base 13.4–17.7% of total length, base equal to height, slightly emarginate, 12–17 principal rays; caudal moderately long, well forked, tips rounded points; anal long, pointed, with 7 prominent principal rays; pelvics abdominal, low, moderately long, somewhat pointed, broad, with small axillary process and weak fleshy stays, 9–12 rays; pectorals low, long, more or less pointed, 16–18 rays. Scales cycloid, large, somewhat crowded anteriorly, increasing in size from head to tail, 62–83 in lateral series; lateral line complete, at midpoint of side beyond dorsal fin. Peritoneum dark; intestine long, coiled, stomach little differentiated; no pyloric caeca. Vertebrae, including Weberian ossicles, 47–49.



Nuptial tubercles white, horny, well developed on spawning males, on anal fin and lower lobe of caudal fin, absent or weakly developed on females.

Colour Adults dark and pronouncedly countershaded; back, upper sides to just below lateral line and head to just below eye, blue-grey to olive, lower sides, lower part of head and ventral surface, cream to white. A dark lateral band, below the lateral line, from snout to base of caudal fin. Fins immaculate to dusky, dark leading edge, or white edge



with dark behind it, on dorsal and paired fins. Young (to 6 inches or 152 mm length) with three or four diffuse dark spots on sides. Countershading and lateral band darker, more pronounced on breeding males. Above the lateral line in both sexes of breeding individuals, there is an iridescent olive-green to ochre band and a narrow, yellowish stripe between the black lateral band and the white of the ventral surface (Nelson 1968c).

Systematic notes This sucker would appear to be the Pacific slope counterpart of *Catostomus commersoni*, the large-scaled sucker of the plains and eastern Canada. These two species occur together and hybridize in a limited area of the upper Fraser and Skeena rivers in British Columbia. (Nelson 1968c).

Distribution Restricted to western North America. It occurs mostly west of the Rocky Mountains from the Peace River in Alberta and British Columbia, the Nass River in British Columbia, through most of the river drainages from western Montana to the coast, south to the Sixes River in Oregon and in western Utah and northern Nevada.

In Canada, it occurs in Alberta in the Peace River drainage downstream to the junction of the Smoky River, west through the Peace River in British Columbia, throughout British Columbia from the Nass River south, including the Fraser and Columbia rivers, except for streams which flow into the Strait of Georgia.

Biology The largescale sucker spawns in the spring, usually in deeper sandy areas of streams, but at times on gravelly or sandy shoals in lakes. Spawning takes place in British Columbia from late April to late June but usually mid-May to late June, depending on stream temperatures. They enter spawning streams when stream temperature is 46°–48° F (7.8°–8.9° C), and spawn during the day or night, a week or more later than white suckers using the same streams. A female may deposit as many as 20,000 eggs, which are adhesive, demersal, yellow, and average 2.5 mm in diameter before fertilization. Eggs hatch in about 2 weeks. Fry remain in the gravel or on the surface of the sand for the first few weeks until the elongate yolk is absorbed. At this point, the mouth is terminal and they become pelagic. They remain so until the mouth moves to the ventral position (at about 16–18 mm in length) and they then become associated with the bottom.

Growth is generally slow; fry grow to about 20–25 mm by July. Average fork length at various ages, from scale interpretation, was given by Clemens et al. (1939) for Okanagan Lake, as follows:

Age	Avg FL	
	(inches)	*(mm)*
1	1.8	46
2	3.0	76
3	4.9	124
4	6.7	170
5	7.5	190
6	9.0	229
7	11.2	284
8	12.0	305
9	13.4	340
10	14.0	356
11	14.8	376

They also calculated that a largescale sucker from Woods Lake 21.2 inches (540 mm) in length was 15 years of age. These authors expressed the usual concern about the accuracy of age determination by scales for suckers over 5 years of age. McPhail and Lindsey (1970) gave maximum size as 24 inches (610 mm) and maximum known weight as 7 pounds.

This sucker lives in lakes and in large rivers. The young are pelagic until they are about 18 mm in length. As they grow larger, they move toward the bottom and into deeper water. Adults are usually found at depths of only a few feet but have been taken as deep as 80 feet. They are often in large numbers in the weedy shore areas of lakes, in backwaters, and in stream mouths. According to McPhail and Lindsey (1970), fry move inshore into very shallow water to feed in daylight hours, and off into deeper water at night.

The upper lethal temperature has been calculated at 85° F (29.4° C) for fish acclimated at 66° F (18.9° C) (Black 1953).

The most detailed analysis of food of this species in Canada is that of Carl (1936). Composition varies with size of individual, time, and habitat but in adults is almost exclusively bottom invertebrates. The following data represent the percentage of lake-dwelling individuals examined which had eaten the various items from June to December: ostracods, 0–19%, copepods, 0–60%, amphipods 5–50%, Trichoptera, 33–50%, Chironomidae 56–100%, larvae of other aquatic insects, 15–40%, molluscs, 10–67%, fish eggs, 0–58%, diatoms, 0–22%, algae, 5–25%, detritus, 75–87%. The food of immature fish before and after the mouth migrates is planktonic cladocerans, copepods, ostracods, and mites; small amounts of chironomid, trichopteran and ephemeropteran larvae, and small quantities of bottom ooze. Stream fish eat more algae, diatoms, and insects other than chironomids and fewer amphipods and molluscs. A high percentage of fish eggs was present only during the fall spawning period of the kokanee and Pacific salmons.

The young of this species may be eaten by a number of species of fish such as squawfish, and by birds such as mergansers. Adults in shallow spawning streams are doubtless eaten by bears, other mammals, osprey, and eagles. This species occurs in areas where it is relatively free of predation by larger fishes.

Largescale suckers in large numbers could constitute serious food competitors with the young and adults of salmonid fishes.

The parasites of this species listed by Hoffman (1967) were as follows: Protozoa (1), Trematoda (6), Cestoda (5), Nematoda (6), Acanthocephala (6), leeches (1), Crustacea (2). Bangham and Adams (1954) listed parasites of this species in British Columbia by locality. Lynch (1936) and Becker (1962) published original descriptions of parasites found in this species.

This sucker is known to hybridize with the white sucker (Nelson 1968c) and with the bridgelip sucker.

Relation to man As with the other suckers, this species is of little direct or indirect importance to man. The flesh is firm, white, flaky, and edible but bony and not highly favoured. It undoubtedly served as food for interior British Columbia Indians and their dogs. McPhail and Lindsey (1970) suggested it may sometimes be sold in fish and chip shops today.

Like the other suckers, its indirect effect as competitor and egg eater of highly valued salmonids may be exaggerated. Eggs eaten by this species may only be those exposed by superimposition of salmonid nests.

Nomenclature

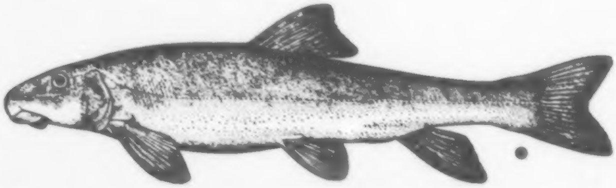
Catostomus macrocheilus — Girard 1857a: 175 (type locality Astoria, Ore.)

Etymology *Catostomus* — inferior mouth; *macrocheilus* — large lip.

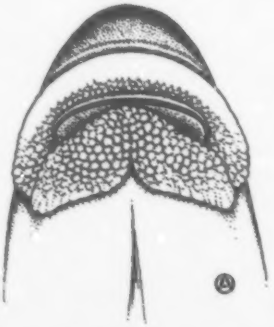
Common names Largescale sucker, coarsescale sucker, Columbia River sucker. French common name: *meunier à grandes écailles*.

MOUNTAIN SUCKER

Catostomus platyrhynchus (Cope)



Description A small, shallow, cylindrical sucker, body torpedo shaped, cross section at dorsal fin almost round, length usually 6–8 inches (152–203 mm); little compressed laterally anterior to dorsal fin, greatest depth near origin of dorsal fin 15.4–20.9% of total length, caudal peduncle long and only moderately deep, depth 6.3–8.0% of total length. Head short, about 16% of total length, not deep but moderately wide, interorbital width 38.4–47.3% of head length; eye diameter 38.8–66.6% of snout length, high on head, at midpoint of head length; snout fleshy, broad and heavy, rounded, length 42.8–50.0% of head length; mouth ventral, large,



lips often exceed width of head, overhung by snout, protrusible, suctorial; gape reaching to between nostril and eye; cartilagineous sheath of lower jaw obvious even when mouth closed, less rounded than in bridgelip sucker, lower lip the shape of paired wings, anterior edge markedly convex, covered with large, round papillae, cleft shallow, incomplete, with 3–5 rows of papillae crossing base, pronounced notch at point of lateral connection of upper and lower lips, upper lip large, its anterior edge a thick fold with no papillae visible from front; no teeth in mouth, pharyngeal teeth flat and comblike. Gill rakers 23–37 + 31–51. Branchiostegal rays 3. Fins: dorsal 1, soft rayed, height greater than base length which is 10.5–14.5% of total length, edge slightly emarginate, 9–11 principal rays in material examined, 8–13 over whole range; caudal not long, not deeply forked, tips rounded points; anal long, height almost 3 times base length, 7 prominent rays; pelvics abdominal, under middle of dorsal fin base, broad, membranous stays and axillary process obvious, tip rounded, 9 or 10 rays; pectorals long, tips pointed, 15 rays. Scales small, cycloid, crowded towards head, 79–89 in lateral series in British Columbia, 60–108 over the whole range; lateral line complete, straight and at midpoint of body beyond pectoral fins. Peritoneum black or dusky; intestine long (6 times standard length), 6–10 coils anterior to liver, little differentiated; no pyloric caeca; swim bladder of 2 chambers, posterior chamber slender, extending to origin of pelvic fins. Vertebrae, including Weberian ossicles, 42–46.

Nuptial tubercles in both sexes, larger and more abundant in males. Present on males on anal fin, lower lobe of caudal fin, caudal peduncle, dorsal surface of paired fins, entire surface of body (minute). Present on females on anal fin, lower lobe of caudal fin (minute), caudal peduncle, dorsal surface of paired fins, dorsal and lateral parts only of head and body (minute). *See* Smith (1966) and Hauser (1969) for more details, size, and location.

Colour Back, head above eyes, and sides to lateral line green, grey, or brown, speckled with black, lateral line not prominent, ventral surface of head and body pale yellow to white, a dark green to black lateral band and/or five dorsal blotches of fine black pigment, fins colourless or faintly red. Breeding individuals more highly coloured, an orange to deep red lateral band, fin rays darker.

Young markedly countershaded dark green above, white below, three dark vertical bars and black peritoneum obvious.

Systematic notes This species was long known as *Pantosteus jordani* Evermann. *See* Smith (1966) for detailed discussion of problems associated with original description, relationship to *P. platyrhynchus* Cope, and reasons for reducing *Pantosteus* to a subgenus of *Catostomus*.

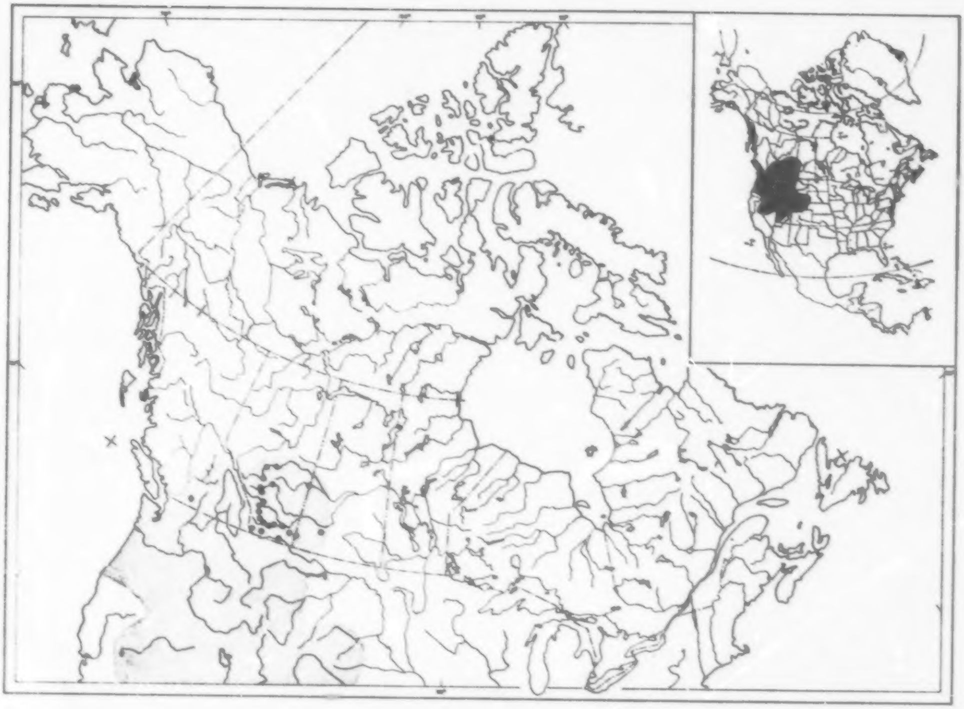
After the combination of mountain sucker populations under *C. platyrhynchus*, the old common name prefix northern, used for *P. jordani*, was no longer applicable.

Distribution The mountain sucker is restricted to the fresh waters of the mountainous regions of western North America. It occurs from western Saskatchewan south through Montana, western South Dakota, Wyoming, west through Utah, northern Nevada to east-central California, north through Oregon and Washington (less abundant) to southern British Columbia.

In Canada, it occurs in the South Saskatchewan and Milk rivers in Saskatchewan and Alberta, and in the Similkameen (Columbia River) and North Thompson (Fraser River) rivers of British Columbia. This species was first recorded in British Columbia in 1955, and Alberta in 1957 (Scott 1957a), and nowhere is it abundant or widely distributed.

Biology Virtually nothing is known of the biology of this sucker in Canada and little from elsewhere. Most of the following was taken from Smith (1966) and Hauser (1969).

Mountain suckers spawn in riffles adjacent to pools of swift mountain streams, for a short period in late spring to early summer (last week in June and first 2 weeks in July), when



water temperature is 51°–66° F (10.5°–18.8° C). Females 5.1–7.2 inches (131–184 mm) total length, bear 990–3710 eggs. Even in fully mature females there is a direct relation between length and egg number. Probably no nest is built; the ripe eggs, which are demersal and probably adhesive, are, depending on size of female, 1.5–2.2 mm in diameter, yellow and translucent. There are smaller, recruitment eggs in the ovary as well.

Growth is slow in this environment and some fry reach 9 mm in July, and 1.2–1.4 inches (29.5–36.0 mm) total length by mid-September. Most fish have formed an annulus on the scales by mid-June of the following year. Ages by scales corresponded to those by otoliths and although difficult to interpret, seemed reliable. The suckers at time of first annulus formation were 2.9–3.8 inches (49–73 mm) total length. The mean total length at capture for various ages for specimens from Flathead Creek, Mont., was given by Hauser as follows:

Age	Mean TL	
	(inches)	*(mm)*
1	3.6	93.0
2	4.5	116.8
3	5.1	131.0
4	5.9	151.0
5	6.6	168.2
6	7.2	183.0
7	8.0	204.4
8	8.4	215.2
9	8.9	226.5

The smallest mature female was 5 inches (127 mm), and all females over 5.7 inches (145 mm) total length were mature. Corresponding figures for males were 4.7 inches (122 mm) and 5.1 inches (130 mm). All Montana specimens became mature between 3 and 5 years of age, males often a year earlier than females. Smith (1966) said maturity came by the second year and sometimes the first year for males.

The largest individual seen by Hauser was apparently 8.9 inches (226 mm). Smith

(1966) gave maximum size as 6.9 inches (175 mm) standard length.

Small mountain suckers are usually found in cover in shallow water of moderate current. Larger young were associated with weedy, intermittent side channels or deep pools. During late winter and spring, adults were found adjacent to pools in 3–8 feet of water, usually with rubble bottoms, from sea level to 8400 feet altitude. After spawning, the habitat was associated with bank cover in deep pools, often in small isolated schools. They occur in lakes only rarely. Summer stream temperatures usually vary from 60° to 74° F (15.5°–23.3° C).

Food in Montana was diatoms, other algae, higher plants, dipterous larvae and pupae. Diatoms, *Closterium*, and filamentous algae were the most important parts of the diet. Turbellaria, Ephemeroptera, Rotifera, and Plecoptera were infrequently eaten. This more or less bears out the statement by Carl et al. (1967) that the horny edges of the jaws would suggest that this species scrapes algae off rocks.

Small mountain suckers may be preyed on by stream salmonids and spawning adults by birds and mammals, but adults probably have few fish predators. Their algae-eating diet probably precludes any important competition with salmonids.

The only parasite listed by Hoffman (1967) for the mountain sucker was the trematode *Posthodiplostomum minimum*. This probably indicates the degree to which parasite determination has been carried out for this species rather than freedom from parasites.

This species is known to hybridize with the white sucker, longnose sucker, Tahoe sucker (*Catostomus tahoensis*), the Utah sucker (*C. ardens*), and *C. discobolus* (Smith 1966).

Relation to man This species, although edible, is so small and so scarce in Canada as to suggest it has never been an important item of food for man or beast. Its algae diet even precludes it being of indirect relation to man as a competitor of, or predator on, other fishes which he values. So, it has virtually no direct or indirect relation to man. It is used and reared for use as a bait fish in the United States and used as food for fur-bearing mammals.

Nomenclature

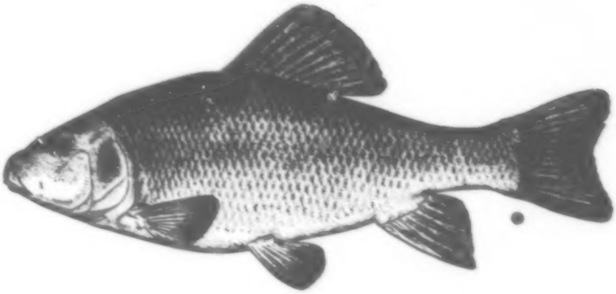
Minomus delphinus — Cope 1872: 435 (type locality tributary of Green River, Wyo.)
Pantosteus jordani Evermann — Jordan and Evermann 1896–1900: 171
Catostomus platyrhynchus (Cope) — Smith 1966: 58

Etymology *Catostomus* — inferior mouth; *platyrhynchus* — flat snout.

Common names Mountain sucker, northern mountain sucker, plains mountain sucker, Jordan's sucker. French common name: *meunier des montagnes*.

LAKE CHUBSUCKER

Erimyzon sucetta (Lacépède)



Description A small sucker, seldom, if ever, exceeding 10 inches (254 mm) in length in Canada and often mistaken for a large minnow. Body robust and deep, back arched, greatest depth at origin of dorsal fin 24.1–27.6% of total length, strongly compressed laterally, cross section at origin of dorsal a broad oval flattened at the bottom; caudal peduncle thick and its depth 8.6–9.9% of total length. Head about 20% of total length, deep, forming a rather steep angle, wide, interorbital width 41.4–45.6% of head length, interorbital area rounded, not flat; eye high, in centre of head length, diameter 33.3–45.0% of snout length; snout moderately long, 40.0–45.6% of head length, bluntly rounded; mouth protrusible, suctorial but very small and only slightly inferior, almost terminal, somewhat oblique, gape only half way to nostril; posterior edge of lower lip forming 90°–100° angle, very little cleft, papillae coarse, long ridges, upper lip much reduced, fine ridgelike papillae on inner surface only, often inconspicuous in deep groove which separates it from snout; no teeth in mouth, pharyngeal teeth short, close, club-shaped. Gill rakers short, 31–35 in material examined. Branchiostegal rays 3. Fins: dorsal 1, soft rayed, origin well ahead of centre of body, appears large for animal's size, base length 15.5–17.9% of total length, height about equal to base length, edge rounded in adults but straight in young, 10–12 heavy rays; caudal not markedly long but broad, only shallowly forked, and tips rounded; anal prominent, height twice base length, origin well behind dorsal insertion, base enclosed in scales, tip pointed, edge square to slightly emarginate, markedly falcate in breeding males, 7 rays, anterior 2 fleshy, heavy; pelvics abdominal, not long, with narrow base, no noticeable axillary process, tip rounded, 8 or 9 rays; pectorals low, moderately broad, tips a rounded point, 15 or 16 rays. Scales large, exposed portion deeper than long at deepest part of body, little crowded near head, 39–42 in lateral series; no lateral line. Peritoneum silvery; intestine long, several coils, undifferentiated; no pyloric caeca. Vertebrae 31 or 32.

There are small nuptial tubercles in rows on the rays of the anal fin and 3 or 4 larger, isolated, tubercles which form a triangle on the snout.

Colour Dorsal surface of back, upper sides and head to level of mouth, bronze to deep olive-green and scales with dark edges creating vague crosshatched pattern; lower sides golden to silvery, lateral band light and vague, or vague vertical bars in largest individuals; lower head, mouth, and ventral surface of body green-yellow to yellow; unpaired fins olive, paired fins dusky or whitish. No marked difference in pattern of breeding individuals, colours intensified and darker. Young silvery to golden with very dark, very wide band from base of tail to eye and downward to snout, caudal fin sometimes reddish and anterior edge of dorsal fin black.

Systematic notes Usually considered to consist of two subspecies, *E. s. sucetta*, coastwise east of the Allegheny Mountains, and *E. s. kennerli*, Great Lakes and west of the mountains. Hubbs and Lagler (1964) mentioned the possibility of an undescribed form in the south-central tributaries of Lake Ontario (New York). Differences given were average ray counts, scale counts, and body depth (Hubbs 1930a). There is insufficient Canadian material available to us to judge how well it fits in the characterization of *E. s. kennerli*.

Distribution Restricted to eastern North America. It occurs from the southern half of New York to southern Florida, west to southern Texas, north through Arkansas, eastern Missouri, Illinois, to southeastern Minnesota, southern Wisconsin and Michigan, and extreme southern Ontario. Apparently rare in the midwest United States.

In Canada, this species is known only from Ontario, in western Lake Erie, ponds tributary to Rondeau Bay, ponds on Long Point and Point Pelee, and from Lake St. Clair. It was listed for Ontario as early as 1929. Specimens were first taken in Canada in 1949 (Scott 1952) and are still rare.

Cox (1896b), claimed *Erimyzon sucetta* Jordan occurred in the lower Saint John River, N.B. If this report, based on the fact that Adams (1873) listed *Moxostomus oblongus*, had any validity the fish might have been the closely related creek chubsucker *Erimyzon oblongus* which occurs in Maine. Neither species is known from New Brunswick today (Scott and Crossman 1959).

A record of the chubsucker in the Hudson Bay watershed by Lower (1915) must have been a misidentification of a shorthead redhorse.

Biology Nothing is known of the biology of this fish in Canada. The following is taken from Cooper (1935) and a summary of United States information by Carlander (1969). These fish spawn in March to April, usually in streams, but in rearing ponds with no streams, eggs were laid over beds of aquatic moss, among masses of filamentous algae or on grass stubble. Spawning lasts about 2 weeks and can take place as late as early July. The male cleans a gravelly area for a nest or eggs are scattered. Depending on size of female, egg number is 3000–20,000 and eggs are 2 mm in diameter, and nonadhesive. The eggs hatch in 6–7 days at temperatures of 72°–85° F. Fry, on hatching, are 6–7 mm. Growth rate during the first month in Michigan was 0.5 mm per day. Ages can be readily determined from scales.

Average calculated total length at each annulus for chubsuckers in Jones Lake, N.C., was as follows:

Age	Avg calc TL	
	(inches)	*(mm)*
1	2.1	53
2	5.3	135
3	7.6	193
4	9.6	244
5	11.2	284
6	12.0	305

Ages as high as 8 have been estimated in New York and the largest chubsucker may be an individual from Silver Springs, Fla., which was 15.2 inches (386 mm) long and weighed 2 pounds. It is unlikely that any exceed 8–10 inches (203–254 mm) in Canada.

In Canada, at present, the habitat of this animal would appear to be small, shallow, warm, weedy ponds irregularly connected to Lake Erie and Lake St. Clair.

Food of small chubsuckers is copepods, cladocerans, and chironomid larvae taken from or near the bottom. The food of the adults is probably not markedly different, consisting of a variety of bottom organisms.

The young of this species are probably eaten by a wide variety of other fishes and the adults in Canada would be ideal prey for basses and pikes living in the same habitats.

Hoffman (1967) listed the parasites of this species as follows: Protozoa (2), Trematoda (5), Cestoda (6), Nematoda (6), Acanthocephala (3), Crustacea (7).

Relation to man This species is too rare in Canada to bear any direct or indirect relation to man.

Nomenclature

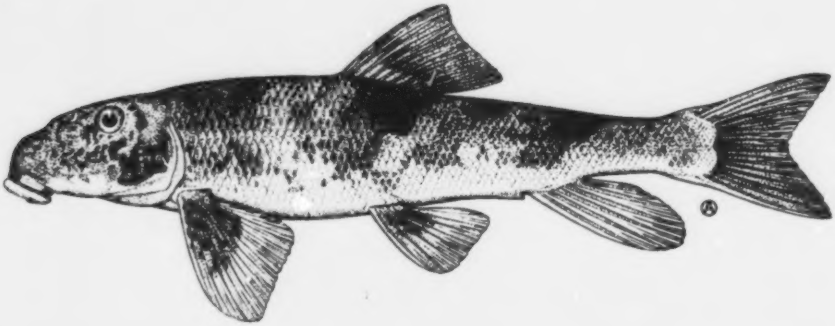
Cyprinus sucetta	— La Cepède 1803: 606 (type locality near Charleston, S.C.)
Moxostoma oblongum	— Gill 1865: 261
Labeo elegans	— Small 1865: 30
Catostomus tuberculatus Lesueur	— Fortin 1866: 73
Erimyzon sucetta Jordan	— Cox 1896b: 64
Moxostomus oblongus (Gunther)	— Cox 1896b: 64
Erimyzon sucetta (Lacépède)	— Jordan 1878b: 144
Erimyzon sucetta oblongus (Mitchill)	— Jordan and Evermann 1896–1900: 186
Erimyzon sucetta kennerlii (Girard)	— Hubbs 1930a: 35

Etymology *Erimyzon* — to suck; *sucetta* — from *sucet*, French for a sucker or sucking fish.

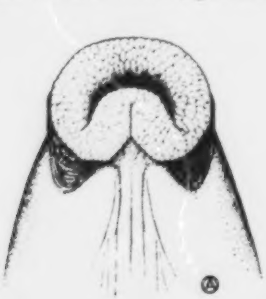
Common names Lake chubsucker, western lake chubsucker, chubsucker, chub sucker, pin sucker. French common name: *sucet de lac*.

NORTHERN HOG SUCKER

Hypentelium nigricans (Lesueur)



Description A smaller eastern sucker, in Canada usually only 5–10 inches (127–254 mm) in total length. The body is cylindrical, not laterally compressed, heavy forward, strongly tapered at the rear, shallow, greatest body depth near origin or dorsal fin, 15.5–18.4% of total length; back flat anterior to dorsal origin; caudal peduncle moderately long and shallow, depth 6.4–7.5% of total length. Head moderately long, about 20% of total length, prominent, bony, square in cross section, wide, interorbital distance 40.0–44.8% of head length, often exceeds body width, deeply concave between the eyes; eye high on head, large, diameter 26.3–37.5% of snout length, and far back on head; snout very long, 59.2–63.3% of head length, strongly curved downward with a distinct dorsal depression over the mouth, bluntly rounded to flat at tip; mouth ventral, narrow, although lips exceed width of snout, protrusible, suctorial but much less retractile than that of most suckers; gape not extending to nostril; lips very large, upper almost as thick as lower, fleshy, almost circular, cleft in lower lip incomplete and inconspicuous; papillae moderate in size, irregular, and round to oval. The distinct similarity of the head, snout, and mouth to the snout of a hog has led to the obvious common name; no teeth in mouth, pharyngeal teeth are slender and prominently hooked. Gill rakers short, about 21 in number. Branchiostegal rays 3. Fins: dorsal 1, soft rayed, a little ahead of midpoint of body, height equal to or less than length of base, base length 11.1–13.5% of total length, little emarginate, 10–13 principal rays; caudal moderately long, well forked, tips pointed to rounded; anal long (longer in males), height about 3 times base length, 7 (rarely 8) rays, anterior ray heavy; pelvics abdominal, low. base narrow, axillary process inconspicuous to absent, tip square, 9 rays; pectorals low, very broad and long, edge square with rounded tip, 15–17 rays, anterior ray heavy. Scales large, not crowded anteriorly, 49–51 in lateral series in material examined; lateral line complete, almost straight and at midpoint of body; peritoneum dusky with some black pigment; intestine long, little differentiated, 5 coils anteriorly; no pyloric caeca; swim bladder of 2 chambers but greatly reduced. Vertebrae 42–45 in material examined.



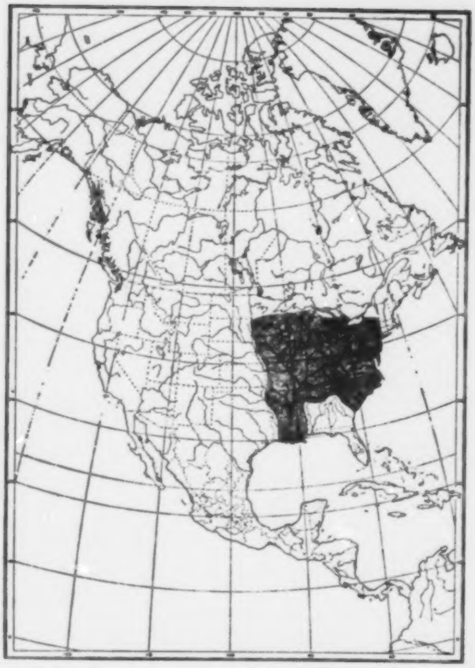
Nuptial tubercles on breeding individuals of both sexes. Those on males large on anal fins, smaller on rays of both surfaces of dorsal, pectoral, pelvic, and lower lobe of anal fins, and on some body scales, the top and sides of the head densely covered with fine tubercles. Females have smaller tubercles, and none on head, body, dorsal fin, or upper surfaces of the paired fins.

Colour Dorsal surface and the head to below the eyes are olive to brown, the sides to below the lateral line are lighter brown to yellow with a brassy sheen, the ventral surface is velvety white. The back and upper sides of young are marked with three dark, oblique saddles (anterior to dorsal fin, at mid-dorsal fin and over anal fin). The sides are marked with dark blotches and irregular spots; all fins are dusky to yellow with varying, irregular amounts of dark pigment more concentrated near the fin base, the leading edge of the paired fins, anal fin, and the ventral lobe of the caudal fin are often white. No precise difference in the colour of males and females even at spawning time.

Distribution This sucker is restricted to fresh waters of eastern North America from southern New York, south along the coast to the northern part of the Gulf states (replaced to the south by the Alabama sucker, *H. etowanum*), west to eastern Oklahoma, north through extreme southeastern Kansas, through Missouri, eastern Iowa, southeastern Wisconsin, east across Wisconsin and Michigan into southern Ontario.

In Canada, it occurs only in southwestern Ontario, in streams south of the Maitland River tributary to lower Lake Huron, lakes St. Clair and Erie and western Lake Ontario to about the Humber River. Many older accounts list Lake of the Woods but the specimens on which the report originated were misidentified white suckers.

Biology Virtually nothing is known of the biology of this sucker in Canada. The following is taken largely from Raney and Lachner (1946).



Spawning occurs in the spring, usually in May or when water temperature reaches 60° F (15.6° C). It usually occurs in 3–5 inches (76–127 mm) of water in riffles, but sometimes near the shallow sides of pools. Smaller males take up stations on the riffles, larger females swim out of nearby pools, and come to rest over an area of fine gravel. Two or three males crowd her closely and eggs and milt are emitted during vibrations of the group. As the eggs are extruded, the males become very active, often standing on their heads, their tails at the surface thrashing the water to foam. Spawning acts last about 2 seconds and are repeated every 4–7 minutes. No actual nest is built, but prespawning activity does clean an area of gravel. The demersal, nonadhesive eggs are broadcast and abandoned. *See* Fish (1932) for details and a drawing of the early development of young.

Young-of-the-year in Ohio are 2.0–3.5 inches (51–89 mm) long by October. Annuli are formed by mid-May when water temperature reaches 56°–60° F (13.3°–15.5° C) and age can be readily determined by means of scales. Males grow more rapidly than females in years 1–4. After 4 years of age, females grow faster and achieve a greater size. The relation between age and total length for females in New York is as follows:

Age	TL	
	(inches)	*(mm)*
1	1.6–1.8	42–46
2	3.3–4.1	85–105
3	4.0–6.4	103–163
4	5.9–8.6	151–220
5	7.6–10.8	195–275
6	8.4–11.6	213–296
7	9.1–12.4	232–315
8	12.5–12.6	318–320
9	11.9–13.6	302–346
11	13.7	350

Maximum size according to Trautman (1957) is 24 inches (610 mm) and 5 pounds, but those seen in Canada are rarely, if ever, longer than 12 inches (305 mm). Some larger males mature at 2 years of age and 5.3 inches (135 mm) total length and most are mature at 3 or 7.1 inches (180 mm) in length. Most females mature at 3 years of age (average 6.7 inches or 170 mm total length) but some slower-growing ones not until 4. Sex ratio is approximately 1:1. Maximum age would appear to be 10 or 11 years.

The northern hog sucker inhabits the riffles and adjacent pools of warm, clear, shallow streams with gravel to rubble bottoms. It is infrequently found in shallow lakes near the mouths of streams. The bulky head, tapering body, low expanded pectoral fins, reduced swim bladder, all adapt this species for its life on the bottom of turbulent swift streams. They are quite inactive below 50° F (10° C). Siltation and increased turbidity may be limiting its range in the United States.

The diet consists mainly of insect larvae, crustaceans, and diatoms and other minute vegetation. The fish feeds in the riffles by scraping ooze off the tops of stones and by moving and overturning stones with its head and lips in order to suck up the invertebrates hidden below them.

The young are probably preyed on by other residents of these swift streams and the larger young are known to be eaten by smallmouth bass that live in the same streams. Adults are relatively free of predation. Many species of stream fishes, especially blacknose dace and creek chub, feed heavily on the eggs as they are laid. Its feeding habit on riffles may preclude it being a serious competitor with more valued stream fishes, in fact, other fishes feed at the downstream edge of riffles on material dislodged by the hog suckers ahead.

Parasites listed by Hoffman (1967) for this species were as follows: Protozoa (1), Trematoda (12), Cestoda (3), Nematoda (4), Acanthocephala (2), Mollusca (1), Crustacea (3). Fischthal (1942) described a new trematode, *Triganodistomum hypentelii*, from this species.

Relation to man The flesh is edible but not favoured, as the fish is small and bony. It apparently constituted a minor amount of food in the central United States in the past, but does so no longer. It is not usually considered a sport fish nor is it sought after even though it can be readily caught with a hook and small worm or a wet fly. Where abundant, it could probably provide enjoyment for an angler with light tackle when other fishes were not open to angling. Small adults are used for bait for muskellunge and largemouth bass in the United States. The northern hog sucker, in Canada, has no real direct or indirect relation to man.

Nomenclature

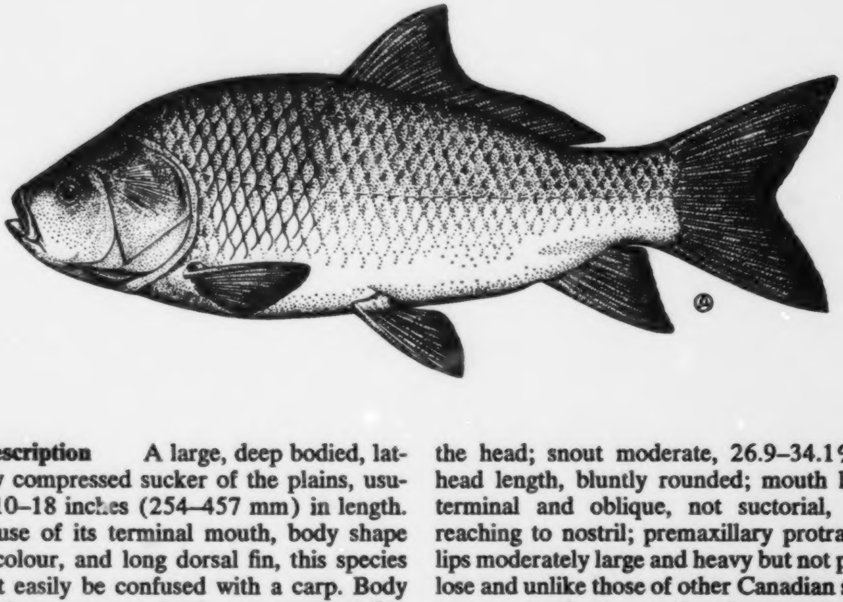
Catostomus nigricans — LeSueur 1817d: 102 (type locality Lake Erie)
Hypentelium nigricans Le Sueur — Hubbs 1926: 22

Etymology *Hypentelium* — below 5 lobes, supposedly in reference to 5-lobed lower lip; *nigricans* — blackish.

Common names Northern hog sucker, northern hogsucker, hognose sucker, hognosed sucker, black sucker, riffle sucker, bighead sucker, stoneroller, hogmolly. French common name: *meunier à tête carrée.*

BIGMOUTH BUFFALO

Ictiobus cyprinellus (Valenciennes)



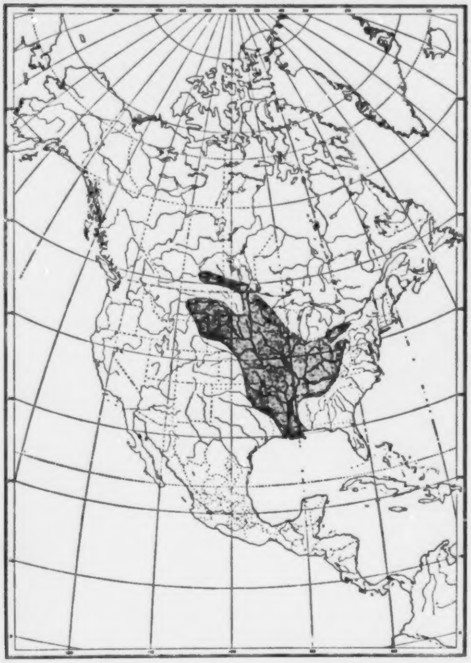
Description A large, deep bodied, laterally compressed sucker of the plains, usually 10–18 inches (254–457 mm) in length. Because of its terminal mouth, body shape and colour, and long dorsal fin, this species might easily be confused with a carp. Body very deep, greatest depth over pectoral fins 29.7–33.7% of total length; cross section at dorsal fin origin a deep oval, somewhat pointed at top and broader at bottom; caudal peduncle very short and deep, depth 10.2–11.6% of total length. Head naked, moderately long, 20–25% of total length, wide, interorbital width 33.8–46.1% of head length, deep, rising sharply to the high back, opercle wide, deep, and strongly marked with radiating lines near top; eye large, diameter 48.0–60.5% of snout length, not so high on head as other suckers, in the anterior third of the head; snout moderate, 26.9–34.1% of head length, bluntly rounded; mouth large, terminal and oblique, not suctorial, gape reaching to nostril; premaxillary protractile; lips moderately large and heavy but not papillose and unlike those of other Canadian suckers; no teeth in mouth, pharyngeal teeth present. Gill rakers, each with many lateral projections, on both sides of arch, those on anterior edge of first arch long, fine, closely spaced, at least 60 in number (*see* Johnson 1963). Branchiostegal rays 3. Fins: dorsal 1, soft rayed, origin ahead of midpoint of body, moderately high, height about half base length, base very long, 28.0–34.2% of total length, 27 or 28 rays in material examined, 23–30 elsewhere; caudal moderately long, very broad, moderately forked, tips pointed; anal origin under dorsal insertion, fin height less than twice length of base, edge slightly emarginate, tip rounded to pointed, 7 or 8 rays, 8–10 to the south; pelvic abdominal, low, narrow, base, stays and axillary process absent or inconspicuous, edge rounded to pointed, 10 or 11 rays; pectorals not long, tip a rounded point, 14 or 15 rays. Scales large, exposed area deeper than long, not crowded forward, 39–41 in lateral series of material examined; lateral line prominent, complete, almost straight, and at midpoint of body. Peritoneum black; intestine very long, at least 4 loops, little differentiated; no pyloric caeca. Vertebrae 36 or 37.

Apparently no noticeable nuptial tubercles on either sex.

Colour Back, upper sides, and head to below eyes a dull brown to olive, sides lighter, ventral surface white, fins dusky to grey. At spawning time, top of head, back, and caudal peduncle slate to greenish, upper sides of head olive-green, upper sides more coppery, pale green to bluish, dorsal and caudal fins drab grey, anal fin olive, pelvic fins lighter, pectoral fins dull white under olive (Forbes and Richardson 1920).

Distribution Restricted to central North America. It occurs from Lake Erie (possibly native and introduced) south through the Ohio and Mississippi River basins to the Tennessee River in northern Alabama, west to Arkansas, south to near the Gulf of Mexico in Louisiana, northwest through eastern Texas and Oklahoma (rare), north through Iowa and South Dakota to the Milk River in central Montana. From Illinois in the Mississippi River drainage northwest through western Minnesota and north in the Red River into Manitoba and west into Saskatchewan. Introduced in Arizona and California.

In Canada, it occurs only in western Lake Erie (rare), the Red and Assiniboine rivers in Manitoba (rare to absent now), and west in the Qu'Appelle River system to central Saskatchewan where it is, in places, abundant. The first published record for this species in Canada may have been that of Gilchrist (1888) under the name *I. Bubalus*. Long known in the Ohio waters of Lake Erie it was first taken from the Canadian waters in 1957 (Scott 1957b) when an individual weighing 18 pounds 2 ounces was caught by a commercial fisherman in Long Point Bay. Records by Hubbs and Lagler (1947) and Dymond (1947) of the closely related *I. bubalus*, smallmouth buffalo, were based on Halkett's 1913 record. There are no authentic Canadian records of *I. bubalus*.



Biology Contrary to most cases, a study of the biology of this species in Canada, by Johnson (1963), is often quoted for biological information by recent texts on fishes in the United States.

Spawning takes place in the spring, for a very short period from mid-May possibly to early June and is at its height when water temperatures are 60°–65° F (15.5°–18.3° C). Adults move out of lakes and large rivers into small tributary streams and into marshes or flooded lake margins in order to spawn. Onset of spring freshets and flooding is apparently necessary to initiate spawning activity. Spawning takes place in shallow water with considerable activity and splashing. A female 26.2 inches (665 mm) long was estimated to have about 750,000 eggs. The eggs, which are 1.2–1.8 mm in diameter when preserved, are adhesive and adhere to vegetation. No nest is built, the eggs are scattered and abandoned. Eggs apparently hatch in approximately 2 weeks. By late June, the young are approximately 18 mm long and by August have grown as large as 2.5 inches (64 mm). Johnson presented an age–fork length relation for fish 3–20 years from several lakes, where age is the number of winters completed, as follows:

Age	FL *(inches)*	FL *(mm)*
3	5.6–8.3	142–211
4	10.1–14.0	257–356
5	9.4–15.7	239–399
6	11.4	290
7	11.8–16.9	300–429
8	13.0–19.0	330–483
9	14.8–18.7	376–475
10	15.5–18.2	394–462
11	16.9	429
12	20.5–24.6	521–625
15	21.7–24.0	551–610
18	24.5–25.5	622–648
20	27.4	696

He stated, however, that whereas age determination by scales was reliable to age 10, over age 10 the estimates were progressively less reliable. Growth is much slower in Saskatchewan than in the south. Fish in Pasqua Lake, Sask., 9 years of age, are only as large as fish 3 years of age in Tennessee. The largest bigmouth buffalo taken in Johnson's study was a female 31.1 inches (791 mm) fork length, which weighed 25.5 pounds. Females grow larger than males as the largest male was 26.1 inches (663 mm) fork length.

Males reach sexual maturity at sizes smaller than females. Some males mature at 12 inches (305 mm) and most are mature by 15 inches (381 mm) fork length. Females as large as 18.7 inches (475 mm) were immature but females over 20 inches (508 mm) usually were mature. Females in Saskatchewan do not spawn every year. Spawning occurs much younger in populations to the south and they probably spawn yearly.

Maximum weight for this species has been reported as 80 pounds from Spirit Lake, Iowa. Maximum age may exceed 20 years.

Bigmouth buffalo inhabit shallow depths in slow, sluggish, or still water of larger rivers, oxbow and flood plain lakes, sloughs, bayous, and shallow lakes. They are well adapted to reservoirs and apparently tolerant of turbid water. They tend to occur in schools of about 25 individuals. On warm still days they spread out over the surface of a lake where they rest quietly, often with the dorsal fin projecting, and often in the midst of clumps of dense algal bloom. Individuals are often hit by fast-moving boats at this time.

This species, unlike other suckers, eats planktonic as well as bottom organisms. Cladocera and copepods are the most important food of the young with chironomid larvae next and small amounts of aquatic beetles, amphipods, nauplii, ostracods, and diatoms often present. In larger young, entomostraca are most important providing about 75% of the food. Smaller quantities of aquatic beetles, aquatic bugs, molluscs, and amphipods were also eaten. Diatoms are not an important food of older fish. Johnson (1963) gave a detailed analysis of stomach contents by size and time. This species swims about, at an angle of 55° to the bottom, bouncing with short up-and-down motions, searching through the mud and debris. The food items are drawn into the mouth and the numerous fine, long gill rakers retain small food particles. Johnson estimated that this species occupies a food niche overlapping bottom feeders and limnetic plankton feeders.

Bigmouth buffalo share an environment with large predaceous fishes such as northern pike, black bullhead, burbot, yellow perch, and walleye, but suffer very little predation from them. The gibbous body may make them hard to engulf. Certainly large adults are probably free of predators of any type.

In Saskatchewan, production seems to be limited by proper water flow to initiate the spawning and survival of young. Strong and weak year classes are very apparent.

Johnson reported only *Argulus appendiculosus* and Myxosporidia as parasites of this species in Saskatchewan. Hoffman (1967) listed the following for this species over the whole of its range: Trematoda (2), Cestoda (5), Nematoda (2), Acanthocephala (3), leeches (1), Crustacea (2).

Hybrids between this species and the smallmouth buffalo are known in Ohio. Hybrids between the bigmouth and black buffalo have been cultured.

Relation to man This species is of considerable commercial importance in the Mississippi River and large quantities are caught annually. In Saskatchewan, it supports a small commercial fishery but is regarded as a rough fish and thought by anglers to be detrimental to game fish. It could constitute a ready but presently little-used supply of high protein food there. They have a high potential for pond culture. A pond of 0.1 acres in Kansas yielded 256 pounds per acre, without fertilizing the pond or feeding the fish. Populations exceeding 1000 pounds per acre have been known in tributaries of the Mississippi River. In 1966–67, complete winter-kill of the fish in Buffalo Pound Lake, Sask., revealed that the bigmouth buffalo had been the dominant species there. The flesh is edible, firm, but coarse. It is not highly prized as table food, however.

Not usually considered a sport fish, but sometimes caught when angling for other species.

The blood of this species and the smallmouth buffalo, in common with only a few other fishes, contains unique cells of unknown function referred to by Chlebeck and Phillips (1969) as secretory granulocytes.

Nomenclature

Sclerognathus cyprinella Valenciennes — Cuvier and Valenciennes 1844 vol. 17: 477 (type locality Lake Ponchartrain, La.)
Ictiobus Bubalus — Gilchrist 1888: 306
Ictiobus cyprinella (Cuvier and Valenciennes) — Eigenmann 1895: 107
Ictiobus bubalus Rafinesque — Halkett 1913: 58
Macrostomatobus cyprinella (Cuvier and Valenciennes) — Hubbs 1926: 19
Megastomatobus cyprinella (Cuvier and Valenciennes) — Hubbs and Greene 1928: 387
Ictiobus cyprinellus (Valenciennes) — Bailey 1951: 191
Megastomatobus cyprinella (Valenciennes) — Scott 1957b: 22

Etymology *Ictiobus* — bull or buffalo fish; *cyprinellus* — diminutive of *Cyprinus*, little carp.

Common names Bigmouth buffalo, redmouth buffalo, common buffalofish, buffalo, buffalofish, gourdhead buffalo. French common name: *buffalo à grande bouche*.

SPOTTED SUCKER

Minytrema melanops (Rafinesque)

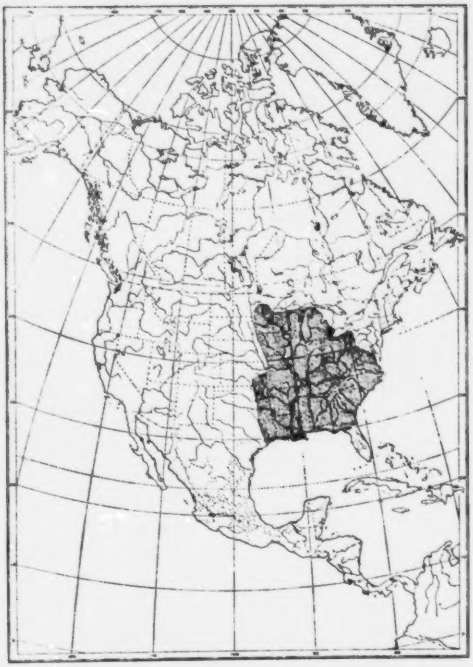
Description Body rather elongate, subcylindrical like white sucker as young, but more laterally compressed like redhorses with age. Usually 9–15 inches (229–281 mm) in length, body only moderately deep, greatest depth at origin of dorsal fin, 20.5–22.5% of total length, cross section a shallow broad oval; caudal peduncle moderately long and shallow, depth 7.9–8.7% of total length. Head only moderately long, length 19.6–20.8% of total length, shallow, upper surface a shallow angle, rather broad above, interorbital width 45.4–48.2% of head length, somewhat flat to rounded above, naked; eye moderate, diameter 29.2–41.6% of snout length, high on head, about midpoint of head length; snout long, 41.6–47.1% of head length, bluntly rounded; mouth small, horizontal, inferior, protrusible, suctorial, but little overhung by snout, and less than width of head; gape not quite reaching nostril, lips plicate, plicae rather fine and oblong, angle of lower lips near 90°, cleft short, incomplete; no teeth in mouth, pharyngeal teeth short, widely spaced, tips flat. Gill rakers long, about ½ diameter of eye, slender. Branchiostegal rays 3. Fins: dorsal 1, soft rayed, origin ahead of midpoint of body, height greater than base length which is 12.9–14.1% of total length, edge somewhat emarginate, 11 or 12 principal rays; caudal moderately long, well forked, tips rather pointed; anal rather square in young, rounded in adults, height twice base length, 7 rays; pelvics abdominal, under anterior portion of dorsal fin, moderately long, square to rounded, base narrow, axillary process large but inconspicuous, 9 or 10 rays; pectorals only moderately long, tip pointed to rounded, 16 rays. Scales cycloid, rather large, not crowded forward, 44–47 in lateral series, lateral line absent in young, largest adults show intermittent completely developed tubes but lateral line rarely complete or conspicuous. Peritoneum colourless to white; intestine long, little differentiated, 4 or 5 coils; no pyloric caeca; swim bladder of two chambers. Vertebrae usually 43 or 44 to the south.

Nuptial tubercles, on males at least, on anal fin, both lobes of caudal fin, upper surface of snout (large), above and behind eye, lower cheek (few), and lateral areas of gular region on ventral surface of head.

Colour Dorsal surface of head, back, caudal peduncle, and upper sides dark green, olive to brown, most of sides of body and head bronze-green, copper, or silvery, ventral surface milk-white and silvery, a copper lustre everywhere. The conspicuous pattern, on which the common name is based, consists of a rather square, brown to black spot on the base of the exposed portion of each scale, the spots on the sides more conspicuous than those on darker back, and forming 8–10 obvious, horizontal rows over the whole body length beyond the head. The dorsal, caudal, and, sometimes, anal fins grey to olive, paired fins dusky to white. Breeding males have a narrow, chocolate-grey lateral band from tip of snout to base of tail, one above this of grey-pink, one above that dark lavender and the back is usually pale lavender. (Trautman 1957). Young, coppery to silvery, spots absent or apparent only over anal fin base.

Distribution Restricted to eastern North America. It occurs in the lower Great Lakes (excluding Lake Ontario), south through western Pennsylvania, east toward the coast through Virginia, south to northern Florida, west to eastern Texas, north in the eastern part of the states from Oklahoma to southeastern South Dakota, east through southern Minnesota, Wisconsin and Michigan to Lake Erie.

It has long been known in the United States waters of lakes Erie, St. Clair, and Huron and often listed as present or probably present in Ontario (Nash 1908). However, the



first actual specimen known to have been taken in Canadian waters was captured by a commercial fisherman, in late April 1962, in Lake St. Clair. Crossman and Ferguson (1963) reported the authentication of this species in the Canadian fauna and suggested the single individual was a stray. Since that time, other adult specimens have been taken in the Thames River but the species is still rare in Canada. It may have moved north into Lake St. Clair from Lake Erie or south from Lake Huron. Trautman (1957) commented that the species occurred in Lake Erie only as strays and that habitat destruction in the period 1920–1950 appears to be restricting it to the southern part of Ohio.

Biology Apparently very little is known of the biology of this species anywhere and nothing is known over its small Canadian range.

It apparently spawns in late spring or early summer at 59°–64° F (15.0°–17.8° C) in Oklahoma. Young-of-the-year, in Ohio, were 2–4 inches (51–102 mm) in length in October. Adults are usually 9–15 inches (229–381 mm) in length and weigh 6 ounces to 1 pound 12 ounces. Dwarf forms apparently mature as small as 6 inches (152 mm). The largest individual known was 17.7 inches (450 mm) long and weighed about 3 pounds (Trautman 1957). Maximum age would appear to be 6 years. It is assumed that their food consists of molluscs and other invertebrates, mainly immature insects. This species lives in lakes, overflow ponds, sloughs, oxbows and clean sluggish streams with sandy, gravelly, or hard clay bottoms without silt. It seems intolerant to turbidity, pollutants, and clay silt bottoms.

Parasites listed for the spotted sucker by Hoffman (1967) included only the protozoan *Myxosoma microthecum*.

See Carlander (1969) for a summary of the meagre information on United States populations.

Relation to man The young are probably preyed on by other fishes and birds. This species, which is not abundant anywhere, probably does not constitute a serious competitor with more valued fishes. In one report at least (Jordan 1878b), it was said to have been used by humans as food and that it was "pretty good for a sucker, which is not saying much." There is no evidence that it is so used today.

Nomenclature

Catostomus melanops — Rafinesque 1820b: 304 (type locality Falls of the Ohio River)
Minytrema melanops — Nash 1908: 108

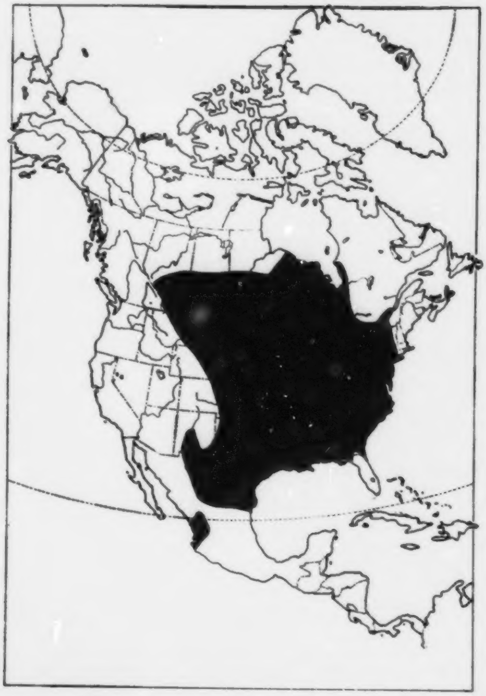
Etymology *Minytrema* — reduced aperture in allusion to imperfections of the lateral line; *melanops* — black spots.

Common names Spotted sucker, striped sucker, black sucker. French common name: *meunier tacheté*.

GENUS MOXOSTOMA — Redhorses

This group of larger, superficially similar, usually laterally compressed suckers, in which the swim bladder consists of three chambers instead of two, is one of the most troublesome groups of freshwater fishes. In a study of some of them, published in 1956, Robins and Raney stated these fishes "have remained one of the most perplexing groups of fishes encountered by American Ichthyologists. Despite the numerous species and the large size . . . very little information is available on the spawning habits, age, growth, and other features of their life history. The gathering of such data has been hindered by the uncertain systematic position and inadequate diagnoses of the species. . . . Except for a brief spawning period, many species occur only in large bodies of water and are not easy to obtain. Meristic features . . . exhibit few interspecific differences. Pigmentation, shape of the fins, relative size and shape of body parts, and detailed structure of the lips have had to be relied upon."

The nomenclature of the group also presents problems, as some species have been published under a variety of names and different authors have combined and separated the various species in different ways. The actual species involved is often difficult to interpret from the names used in lists published before 1930. Robins and Raney recognized three subgenera: ***Moxostoma (M. anisurum, carinatum, duquesnei, erythrurum,*** and ***macrolepidotum), Megapharynx (M. hubbsi and valenciennesi), and Scartomyzon*** which does not have a Canadian representative.

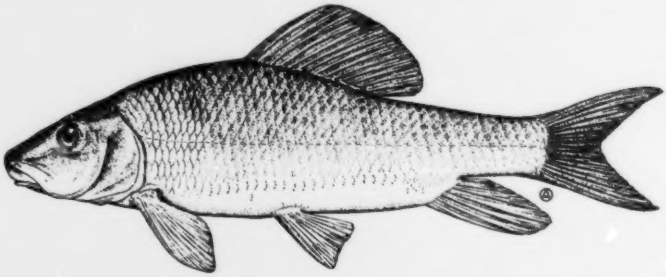

World Distribution of the Redhorses

Because of all these difficulties, the lack of biological information, the lack of reference material, and the limited distribution of many of the species in Canada, the species accounts which follow are, in general, brief. The species descriptions are more detailed in order to provide as many as possible of the characters quoted from Robins and Raney as those on which we must rely for identification. It is hoped that these detailed descriptions will make up for any inadequacies in the key.

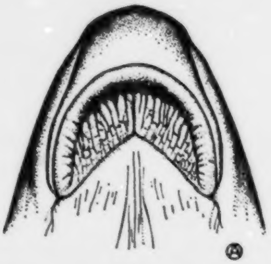
Because of the problems of identification and the confusion in nomenclature, any serious consideration of this group should be undertaken only after examination of a recent thorough study by Jenkins (1970).

SILVER REDHORSE

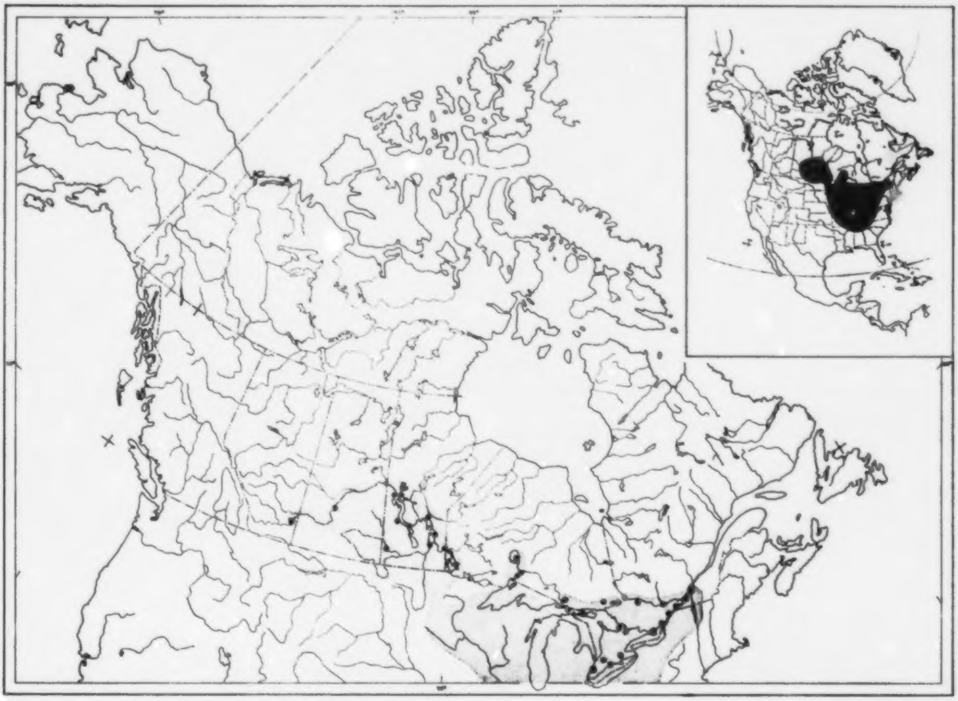
Moxostoma anisurum (Rafinesque)



Description A large, laterally compressed sucker usually about 12–16 inches (305–406 mm) in length. Back with moderately high arch to dorsal fin, tapering behind; greatest depth, at dorsal origin, 20.9–25.9% of total length; cross section there a long, broad oval; caudal peduncle rather narrow, depth 7.8–10.2% of total length. Head naked, moderately long, about 20% of total length; upper and lower surface forming angle of about 40°, moderately broad, interorbital width 41.1–49.3% of head length, and deep; eye moderately large, its diameter 36.8–44.5% of snout length, high on head, at midpoint of head length; snout long 34.2–49.0% of head length, rounded and somewhat bulbous, with a marked groove above mouth; mouth inferior, overhung by snout, protrusible, suctorial, its width less than width of head at mouth, gape barely reaching nostril; lips thick but not overly prominent, upper lip narrow, only inner edge plicate, lower lip wide, edges meeting at 90° or more, deeply cleft, plicae long, narrow, with cross striations; no teeth in mouth, pharyngeal teeth large, and heavy. Gill rakers long, 25–28 in number. Branchiostegal rays 3. Fins: dorsal 1, soft rayed, rather high and long, height about ¾ of base length which is 16.3–19.3% of total length, edge rounded, 15–17 principal rays; caudal moderately long, deeply forked, tips pointed or upper slightly produced and lower rounded; anal long, height 3 times length of base, origin well behind insertion of dorsal fin, pointed, usually 7 rays; pelvic abdominal, origin below fourth dorsal ray, edge square to slightly emarginate, 9 or 10 rays; pectorals low, long, rather narrow, tip round to pointed, 18 rays. Scales cycloid, moderately large, not crowded anteriorly, caudal peduncle scales usually 12(5-2-5), 42–48 scales in lateral line; lateral line complete, at midpoint of body and almost straight. Peritoneum colourless to silvery; intestine long, little differentiated, 5 rounded coils obvious ventrally; no pyloric caeca; swim bladder of 3 chambers. Vertebrae usually 36 plus the Weberian ossicles.



Nuptial tubercles on anal, caudal, and a few on body scales of males, and on anal fin only of females, and barely visible.



Colour Body bronze to olive-green dorsally, sides silvery, often with faint golden reflections, ventral surface silver to milk-white, snout often white. Fins light slate, white, or pale red tint, but they haemorrhage easily and can appear bright red in net-caught specimens. Scales edged with dark pigment but without spots at their bases (Trautman 1957).

Distribution Restricted to the fresh waters of North America. The silver redhorse occurs in the east from the St. Lawrence River, south through central New York, southwest through the western half of the coastal states to northern Alabama, then northwest through eastern Arkansas, Missouri, north to the Red and Souris rivers in northern North Dakota, northwest into Saskatchewan and west to Medicine Hat, Alta. In the north, its range extends east through central Saskatchewan and Manitoba, through the lower Great Lakes to southern Ontario.

In Canada, it occurs in the St. Lawrence River from Lac St. Pierre upstream, the Lake Champlain system, the Ottawa River, across Ontario at the level of the Goulais River just north of Sault Ste. Marie but including Lake Nipigon. Absent from the area between Lake Superior and Lake of the Woods, generally in Manitoba as far north as the source of the Nelson River, west in the Souris, Assiniboine, and Saskatchewan rivers into Saskatchewan, west in the South Saskatchewan River as far as Medicine Hat, Alta.

Biology There is no available published information on the biology of this species in Canada. The following information is largely from Meyer (1962) and based on Iowa specimens.

The silver redhorse spawns in swiftly flowing streams in the spring, generally when the temperature reaches 56° F (13.3° C).

Spawning was observed in the Chippawa River, Ont., on June 9. Even slight changes in temperature effect spawning activity. Males ripen sooner, and arrive on the spawning grounds sooner, presumably to acquire and defend spawning territory. The females are on the spawning grounds for a very short time. Spawning takes place in the main channel of turbid rivers in 1–3 feet of water on gravel to rubble bottoms. They apparently do not ascend tributary streams to spawn.

Egg number in females 13.3–19.3 inches (338–490 mm) in length varied, directly with size, from 14,910 to 36,340.

For details and a drawing of the early development of young *see* Fish (1932).

Growth is moderately fast in this species as compared to other redhorses. The greatest length increment is in the first year and length increments decrease beyond age 2, whereas weight increments continue to increase. Young silver redhorse form annuli in June in Iowa but older, larger individuals complete the formation of an annulus as late as August. The relation between age and observed length and the calculated weight in pounds (Meyer 1962) is as follows:

	Observed TL		Calculated wt
Age	(*inches*)	(*mm*)	(*lb*)
1	4.26	108	0.03
2	6.60	168	0.18
3	11.91	302	0.46
4	13.74	349	0.91
5	15.43	391	1.42
6	17.80	452	2.13
7	19.56	496	2.78
8	20.23	514	3.48
9	20.40	518	3.65

There is no pronounced difference in the growth rate of the sexes, and maturity is reached by both at age 5, in Iowa.

Maximum size may be the specimen listed by Trautman (1957) as 25 inches (635 mm) in length, which weighed 8 pounds 4 ounces. Maximum weight reaches 10 pounds in the Ohio River.

Although they occur in both, silver redhorse are usually more abundant in streams than in lakes. The young of this species inhabit slow-moving waters over hard or soft bottoms where overhanging banks may provide protection from predators. Adults are more common in areas where current is slower and there are long, deep, pools but avoid heavy silt, sedimentation, and pollution. They tend to be sedentary in summer.

This species, never abundant in Canada, has greatly decreased in numbers in Ohio, particularly in tributaries of Lake Erie (Trautman 1957) but is on the increase in Iowa and areas to the south (Meyer 1962).

Silver redhorse apparently feed exclusively on invertebrates which they suck up from the bottom. Individuals over 4 inches (102 mm) in length in Iowa had eaten immature insects such as chironomids, ephemeropterids, trichopterids in that order of frequency, and small molluscs.

The young silver redhorse may be subject to predation by a wide range of warmwater predators in rivers, but the large adults are probably relatively free from it. This species would compete with all river-residing, bottom-feeding fishes but especially with other redhorses and suckers.

Parasites listed for this species by Hoffman (1967) were Protozoa (2), Trematoda (2), Cestoda (1).

Relation to man Apparently in the past (Forbes and Richardson 1920) this species was a highly acceptable food fish and made up a high percentage of the fishes sold as suckers from Lake Michigan. It probably still constitutes a part of commercial catches in the Ohio and Mississippi rivers. It has never been of major importance as commercial or sport fish in Canada but is of small commercial value in the St. Lawrence River and marketed when caught with other species simply as suckers. In Iowa, Meyer estimated that the silver redhorse and two other species of redhorse made up 25% of the weight of fishes in the Des Moines River.

In 1960, a redhorse 24 inches (610 mm) in length, purported to be this species, was captured by an angler in Sparrow Lake, Muskoka District, Ont. It was reported to have provided a two-hour battle. Obviously, where this species is locally abundant they may constitute a potential sport fish of some significance.

Nomenclature

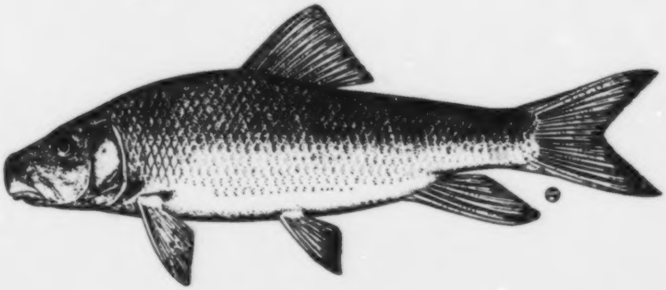
Catostomus anisurus — Rafinesque 1820b: 300 (type locality Ohio River)
Catostomus carpio — Cuvier and Valenciennes 1844: 457
Myxostoma carpio (Valenciennes) Jordan — Jordan 1878b: 118
Myxostoma anisura (Rafinesque) Jordan — Jordan 1878b: 126
Moxostoma valenciennesi — Jordan 1886: 73
Moxostoma anisurum (Rafinesque) — Jordan and Evermann 1896–1900: 190

Etymology *Moxostoma* — sucking mouth; *anisurum* — unequal tail in relation to the differences in the upper and lower lobes of the caudal fin.

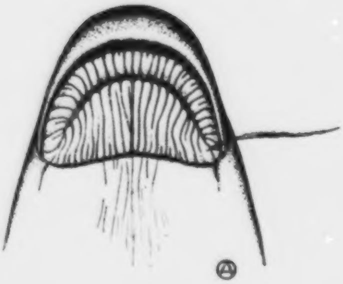
Common names Silver redhorse, silver mullet, white nose redhorse, white nosed mullet, white nosed sucker. French common name: *suceur blanc*.

RIVER REDHORSE

Moxostoma carinatum (Cope)



Description (2 specimens only). This moderately large sucker, usually 12–18 inches (305–457 mm) in length, does not seem so deep bodied as some of the redhorses. Body laterally compressed, but with low arch to back, tapering behind; greatest depth, at dorsal origin, 19.3–22.8% of total length; cross section a broad oval; caudal peduncle rather long and narrow, its depth 6.8–7.8% of total length. Head naked, moderately long, 18.9–20.0% of total length, not particularly deep, its upper surface not at steep angle, flat, very broad, interorbital width 47.9–50.0% of head length; eye moderate, diameter 37.6–39.5% of snout length, high on head about middle of head length; snout rather long, 45.0–46.6% of head length, square rather than bulbous; mouth inferior



but little overhung by snout, protrusible, suctorial, its width only slightly less than width of head at mouth, gape reaching nostril; lips thick but not overly prominent, upper lip narrow with prominent plicae, lower lip wide, at least 3 times width of upper lip, edges meeting in almost a straight line, deeply cleft, plicae long, narrow, without cross striations; no teeth in mouth, pharyngeal teeth large, heavy, club-shaped. Gill rakers long, 22–24 in number in material examined. Branchiostegal rays 3. Fins: dorsal 1, soft rayed, height about equal to base length, which is 12.1–16.0% of total length, edge square, 14 principal rays; caudal long, deeply forked, tips usually pointed, often in large adults upper lobe produced and lower lobe rounded; anal long, height 3 times length of base, origin well behind insertion of dorsal fin, pointed, usually 7 rays; pelvics abdominal, low, origin below seventh dorsal ray, edge square, tip pointed, usually 9 rays; pectorals low, moderately long, rather narrow, edge square with bluntly pointed tip, 15 or 16 rays. Scales cycloid, moderately large, not crowded forward, caudal peduncle scales 12(5-2-5), 42–47 scales in lateral line; lateral line complete, near midpoint of body and almost straight. Peritoneum colourless to silvery; intestine long, little differentiated, 5 or 6 rounded coils obvious ventrally; no pyloric caeca; swim bladder of 3 chambers. Vertebrae 38 plus the Weberian ossicles.

Nuptial tubercles on snout, anal, and caudal fins of males; on anal fin only in females.

Colour Dorsal surface and upper sides brown or olive-green with bright bronze overtone, sides paler, more golden, ventral surface golden to milk white. Dorsal, caudal, and anal fins pale red, anterior rays of pelvic and pectoral fins white, remainder of pelvic fins pale red to olive, and of pectoral fins olive. Each dorso-lateral scale with dark crescent at base.

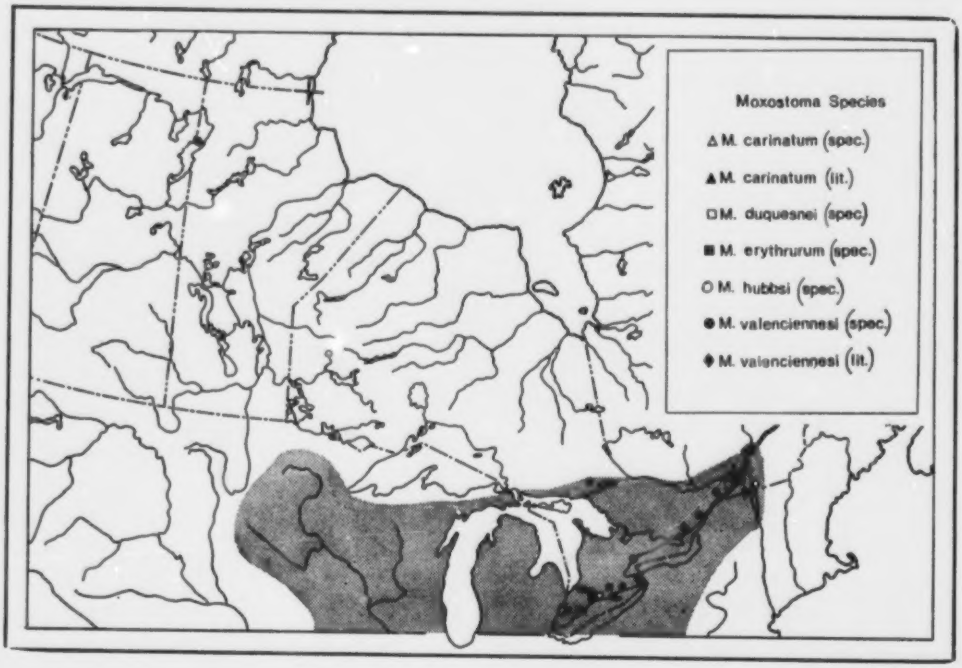
Distribution The river redhorse is restricted to the fresh waters of eastern North America. It occurs in the upper St. Lawrence River, is absent southwest to northwestern Pennsylvania, then occurs west of the mountains south to the Escambia River in Florida, west to the Pearl River, north through Arkansas, eastern Oklahoma to eastern Nebraska, east south of the Great Lakes through southern Michigan and Ohio. Many published range statements do not indicate the disjunct nature of the distribution. Bones found in Indian middens of Lake Erie's southern shores suggest it did occur, prior to the coming of the white man, in the area between the now disjunct areas of distribution.

In Canada, it occurs only in the St. Lawrence River in the area of Lac St. Pierre and Lac St. Louis, in Rivière Châteauguay, and Baie Laprairie below Lachine Rapids. It may occur in Lac des Deux-Montagnes. It probably occurs in the Ottawa River since a single specimen has been taken in Ontario in the Mississippi River, Lanark County, a tributary of the Ottawa. Not known today in even the United States tributaries of the Great Lakes. It was first recorded in Canada by Vladykov in 1942 as *Placopharynx carinatus* Cope.

Biology There is no published information on the biology or life history of this species in Canada. *See* Carlander (1969) for a short summary of information on data in generally unavailable reports.

It presumably spawns in large rivers in the spring but may resort to the upper reaches of some of the larger tributaries of their river habitats for this purpose.

Growth is moderately fast in the United States and the following relation between cal-



culated total length and age for specimens from the Meramec River in Missouri was quoted by Carlander.

Age	Calc TL	
	(*inches*)	(*mm*)
1	2.4	61
2	5.3	135
3	8.1	206
4	10.4	264
5	11.7	297
6	13.8	351
7	16.3	414
8	17.8	452
9	19.8	503
10	20.9	531
11	22.0	559
12	23.5	597

Trautman (1957) stated that the largest Ohio specimen was 29 inches (737 mm) in length and weighed 10 pounds 8 ounces. He also stated that Ohio River fishermen reported weights up to 14 pounds but they were usually 13–24 inches (330–610 mm) in length and 1–7 pounds in weight.

The habitat is apparently the deeper waters of larger rivers and the lower portions of their larger tributaries. River redhorse are abundant in upper reaches of the tributaries of these rivers only at spawning time. They are apparently intolerant of pollution or heavy siltation. This probably accounts for their diminution in numbers in the United States since 1925. It may also account for their disjunct distribution. They may have been continuous and disappeared from the area between the upper St. Lawrence River and the Ohio River. They may have been in Lake Erie in the past but most published records of their presence there would appear to be misidentification. Their intolerence of pollution does not augur well for their survival in the St. Lawrence in the area of Montreal and the outfall of the Ottawa River.

The food of this redhorse, as with the other species, consists of invertebrates swept up from the bottom and probably includes small molluscs and the young of various aquatic insects.

They are probably preyed on by other

fishes only as young, and their size as adults and their elusive nature may preclude serious predation on the adults.

Hoffman (1967) did not include this species in his list of parasites of suckers. This, doubtless, indicates lack of information rather than freedom from parasites.

Relation to man Little is known of the true relation of this sucker to man as a result of its elusiveness, its confusion in the literature and the general practice of marketing all species of suckers simply as suckers or all species of redhorses as mullets. The presence of bones of this species in Indian middens suggests it was eaten by Indians. It doubtless represents a small part of the catch in the Ohio and Mississippi rivers. Vladykov, in his report of this species as new to Canada, stated that it was not rare near Montreal, that the commercial fisherman knew it by a distinct name, that it was a commercial species of minor importance, and that during fall and winter fishing this species constituted about 2% of the catch of catostomid fishes. He said one fisherman caught, in 28 days, 90 river redhorse weighing a total of 360 pounds.

Nomenclature

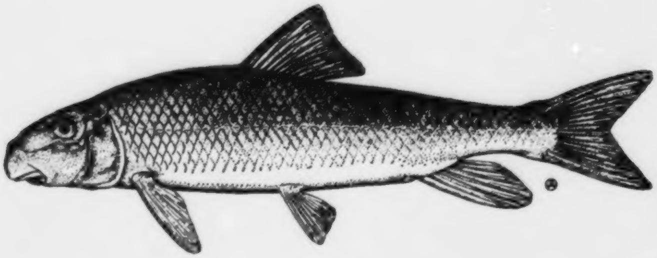
Placopharynx carinatus — Cope 1870: 467 (type locality Wabash River, Lafayette, Ind.)
Placopharynx duquesnii Le Sueur — Halkett 1913: 60
Moxostoma carinatum — Legendre 1952: XI
Moxostoma carinatus — Scott 1954: 43
Moxostoma carinatum (Cope) — Scott 1958: 13

Etymology *Moxostoma* — sucking mouth; *carinatum* — keeled.

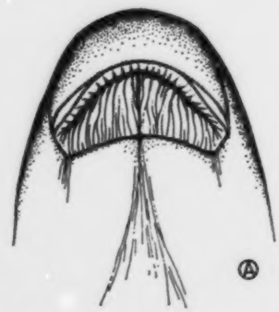
Common names River redhorse, river mullet. French common name: *suceur ballot.*

BLACK REDHORSE

Moxostoma duquesnei (Lesueur)



Description This redhorse, one of the smaller species, is rarely seen larger than 15 inches (381 mm) and is usually 10–13 inches (254–330 mm) in total length. Body laterally compressed but very low arch to back, body shallow; greatest depth 17.6–18.7% of total length; cross section at dorsal origin a wide oval or subcylindrical; caudal peduncle narrow, least depth 6.4–7.0% of total length. Head naked, moderately long, 16.3–17.5% of total length, broad, interorbital width 42.2–45.7% of head length, slightly rounded dorsally, not deep, upper and lower surfaces forming angle of about 30°; eye only moderately large, its diameter 37.2–52.4% of snout length, high on head but at midpoint of head length; snout long, 39.6–49.8% of head length; rounded and bulbous; mouth inferior, considerably overhung by snout, protrusible, suctorial, its width less than head width at this point, gape reaching to point midway between nostril and orbit; lips thick but not prominent, upper lip very narrow, coarse plicae on posterior edge only, lower lip about 5 times as wide as upper, edges slightly concave, meeting almost in straight line, deeply cleft, plicae long, irregular, narrow, no cross striations; no teeth in mouth, pharyngeal teeth large, club-shaped. Gill rakers medium length, 30–32 in number. Branchiostegal rays 3. Fins: dorsal 1, soft rayed, not markedly high, height slightly exceeds base length which is 12.3–14.3% of total length, edge slightly emarginate, 12 or 13 principal rays; caudal long, well forked, tips pointed or dorsal lobe produced and ventral somewhat rounded; anal fin long, height 2½ times base length, origin well behind dorsal insertion, tip with rounded point, 6 or 7 rays; pelvics abdominal, below midpoint of dorsal fin, short, not broad, edge square, 9 or 10 rays; pectorals low, long, narrow, tip a narrow, rounded point, usually 16 rays. Scales cycloid, rather large, not crowded forward; caudal peduncle scales usually 12(5-2-5) but sometimes 13(6-2-5), 47–50 in lateral line; lateral line complete, at midpoint of body, straight. Peritoneum silvery; intestine long, little differentiated, 4 or 5 rounded coils obvious ventrally; no pyloric caeca; swim bladder of 3 chambers. Vertebrae usually 39, plus Weberian ossicles.



Nuptial tubercles on anal and lower lobe of caudal fin in males. Bowman (1970) said he never saw tubercles on females and that in males the tubercles were restricted to the anal and caudal fins. However, there are minute tubercles on the head and body of females and on the head, lateral and dorsal body scales, and all fins of males.

Colour Dorsal surface and upper sides grey or olive-brown with silver-blue overtone, sides lighter and usually silver-blue, sometimes with bronze reflections, ventral surface silvery to milk-white. Fins usually slate grey to orange but the ventral fins are at times tinged with red. Scales usually dark edged but not dark at base (Trautman 1957).

At spawning time males in Missouri developed a light pinkish midlateral band. Above and below this, the body was metallic greenish black, ventral surface white, dorsal and caudal fins slate, anal, pelvic, and pectoral fins deep pink. Mature females showed no colour difference from other times of the year (Bowman 1970).

Distribution (*See* map p. 569) The black redhorse is restricted to the fresh waters of eastern North America as are many of the redhorses. It occurs in the Great Lakes tributaries in the United States, from western New York (drainages of lakes Erie and Ontario) and south, west of the mountains, to central Alabama and northeastern Mississippi, west through northern Arkansas, north through eastern Oklahoma, southern Missouri, southeastern Kansas and northeastern Iowa (rare), southeastern Minnesota, the southern third of Wisconsin and Michigan, and into southwestern Ontario.

In Canada, it is known only from specimens collected from the Grand River (Hubbs and Brown 1929), and from Catfish Creek, tributaries of Lake Erie. Many published statements of the distribution of this species include the upper St. Lawrence River and Lake Champlain drainages. Hubbs (1930a) quoted Greeley for a record from Lake Champlain in New York. It has not, however, been recorded from Quebec and records for the St. Lawrence drainage and Lake Champlain are probably erroneous. Several attempts to collect specimens of the black redhorse in Catfish Creek since 1938 have been unsuccessful and it is possible that the species no longer occurs in Canada. Specimens of this rare species should be carefully watched for in tributaries of Lake Erie.

Biology There is nothing known of the biology of this species in Canada. The following summary is based on Missouri populations described by Bowman (1970). They spawn in the spring, in 0.5–2.0 feet of water on gravel shoals in streams, during the day and night for a period of about 4 days in late April. Stream temperature at spawning time varied, from year to year, from 56°–72° F (13.3°–22.2° C). There is considerable activity, such as jumping out of the water, before males take up territories which they defend. A single female is attended by two males, the three vibrating during actual egg laying. No nest is built, eggs are scattered over the gravel and abandoned. Average number of eggs per female varied, in relation to weight of the female, from 1357 to 6055.

Growth is moderately fast in the south and the relation between age and average calculated total length at the end of each year of life for the Niangua River, Mo., is as follows:

Age	Avg calc TL	
	(inches)	*(mm)*
1	3.3	84
2	5.0	127
3	6.8	173
4	8.4	213
5	9.6	244
6	10.6	269
7	11.3	287
8	11.7	297
9	11.9	302
10	12.8	325

In Ohio, young-of-the-year in October are 2.0–3.5 inches (51–89 mm) in length, adults are usually 10–15 inches (254–381 mm) in length and 6 ounces to 1.5 pounds in weight, Trautman (1957). The largest Ohio specimen was 17.3 inches (439 mm) in length and weighed 2 pounds 4 ounces.

This species is usually looked upon as intolerant of siltation, and an inhabitant of pools in the swifter flowing portions of medium to large streams with clear water and gravel, rock, or sand bottoms. The only stream from which it is known in Canada is usually heavily silted. The turbidity of the Canadian streams tributary to Lake Erie may explain why this species is so rare, and *M. macrolepidotum* and *M. erythrurum* survive. The northern range of this species seems to be decreasing as a result of silting of streams.

Black redhorse are bottom feeders, they suck in bottom material near riffles and expel the silt and waste. Food is entirely invertebrate, composition varies with size and season but in Missouri was composed of Hydracarina, Diptera, Ephemeroptera, Cladocera, Copepoda, Ostracoda, Amphipoda, and Nemathelminthes. No evidence was found of egg predation by this species.

Hoffman (1967) listed the trematodes *Anonchohaptor anomalus* and *Neodactylogyrus duquesni* as parasitic on this species.

Relation to man This species, along with other redhorses, makes up a small percentage of fish marketed in the south as suckers or mullets. Bowman spoke of them taken by angling and by spearing in Missouri. They apparently are not guilty, as often thought, of egg predation on more valuable species and are not serious food competitors of game species such as smallmouth bass.

Nomenclature

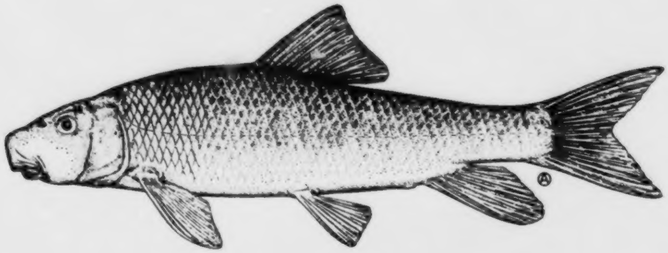
Catostomus Duquesnii	— LeSueur 1817d: 105 (type locality Ohio River at Pittsburgh, Pa.)
Placopharynx duquesnii (LeSueur)	— Dymond 1922: 64
Moxostoma duquesnii	— Radforth 1944: 48

Etymology *Moxostoma* — sucking mouth; *duquesnei* — after Fort Duquesne, an older name for Pittsburgh, Pa., the type locality.

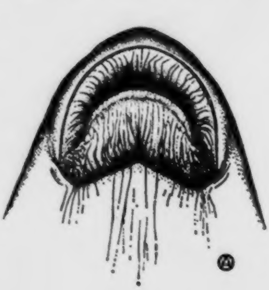
Common names Black redhorse, black mullet, finescale redhorse, finescale mullet. French common name: *suceur noir*.

GOLDEN REDHORSE

Moxostoma erythrurum (Rafinesque)



Description This shallow-bodied redhorse is usually 11–18 inches (279–457 mm) in length. Body laterally compressed, with little or no arch to back, tapering behind; greatest depth at origin of dorsal fin, 18.3–21.3% of total length; cross section a long oval; caudal peduncle rather long and narrow, its least depth 6.6–8.4% of total length. Head naked, of medium length, slightly less than 20% of total length, rounded on top, broad, interorbital width 41.2–47.6% of head length, not deep, upper and lower surfaces forming angle of about 30°; eye moderate, its diameter 37.2–54.1% of snout length, high on head, at midpoint of head length; snout rather long, 40.3–45.8% of head length, round to square, not overly bulbous; mouth inferior, little overhung by snout, protrusible, suctorial, its width at corners less than head width, gape reaching nostril; lips thick but not overly prominent, upper lip moderate in width, with shallow plicae on lower and inner surfaces, lower lip not 2 times as wide as upper, posterior edges meeting at about 100°, moderately cleft, plicae narrow, irregular, with some cross striations; no teeth in mouth, pharyngeal teeth flat, comb-like, and chisel-like. Gill rakers long, 25–27 in number. Branchiostegal rays 3. Fins: dorsal 1, soft rayed, height slightly greater than base length which is 12.7–15.7% of total length, edge slightly emarginate, 11–14 principal rays; caudal long, broad, well forked, tips pointed; anal long, height 2½ times base length, origin behind insertion of dorsal, tip rounded, 7 rays; pelvics abdominal, low, origin below midpoint of dorsal fin, edge square, 9 rays; pectorals low, long, moderately wide, tip bluntly pointed, usually 16 rays. Scales cycloid, large, not crowded forward, caudal peduncle scales 12(5-2-5), 42–44 scales in lateral line; lateral line complete, near midpoint of body, almost straight. Peritoneum colourless to silvery; intestine long, little differentiated, 2 or 3 long coils obvious ventrally; no pyloric caeca; swim bladder of 3 chambers. Vertebrae usually 36 plus Weberian ossicles.



Nuptial tubercles large on snout, anal fin, lower lobe of caudal fin in males. Tubercles on females but difficult to see.

Colour Dorsal surface and upper sides grey to bronze or olive, usually with bronze to golden cast in adults and large young, silver cast in smaller individuals, sides paler with bronze-silver overtone, ventral surface silver to milk-white. Dorsal and caudal fins light slate grey, anal and paired fins white to pale orange, or all fins orange to red-orange. Scales golden green at bases but without dark spots (Trautman 1957).

Distribution (*See* map p. 569) The golden redhorse is restricted to the fresh waters of eastern North America. It occurs south from Lake Ontario tributaries of western New York, west of the mountains, through the western parts of Pennsylvania and West Virginia to Tennessee and the north of Georgia, Alabama and Mississippi, west through much of northwestern Arkansas, eastern Oklahoma, and extreme northern Texas, north through southeastern Kansas, through the eastern parts of the states from Nebraska to North Dakota, east across central Minnesota, Wisconsin, Michigan, and into Ontario.

In Canada, it occurs only in Ontario in the drainages of Lake Erie, Lake St. Clair and southern Lake Huron. It is present in the Lake Erie system at least as far east as the Grand River where it occurs with *M. macrolepidotum*, *M. valenciennesi*, and *M. anisurum* but not apparently in the Niagara River where *M. macrolepidotum* and *M. valenciennesi* are common.

Biology Nothing is known of the biology of this species in its limited distribution in Canada. The following life history details are taken from Meyer (1962) for the Des Moines River, Iowa, and from the summary of data in Carlander (1969).

They spawn in spring, later than other redhorses in the same area, usually in mid-May in Iowa, when water temperature reaches 59°–60° F (15.0°–15.5° C). Spawning takes place in riffles in the main stream, spawning adults apparently do not ascend smaller tributaries. Spawning lasts for only a short period. Males arrive on spawning grounds first where they establish and defend territories but no nest is built and at spawning the eggs are scattered and abandoned. Average egg number for females 11.5–15.7 inches (292–399 mm), 4–6 years of age, ranged from 6100–25,350 in Iowa but estimates ran as high as 35,000 in Ohio.

Growth of this species in Iowa was slower than that of other redhorses. Trautman (1957) cited length of young-of-the-year in October as 2.5–4.5 inches (64–114 mm). The relation between age and mean length at capture for golden redhorse in the Des Moines River was given as follows:

Age	Mean length	
	(*inches*)	(*mm*)
1	4.9	124
2	7.4	188
3	10.4	264
4	11.4	290
5	12.8	325
6	18.6	472
7	19.2	488

Data from Oklahoma indicated that the size range for age 7 there was 23.1–24.6 inches (587–625 mm). Trautman gave maximum size from Lake Erie as 26 inches (660 mm) in length and a weight of 4.5 pounds. He stated that the usual length was 11–18 inches (279–457 mm). The heaviest individuals are apparently females. Scott (1967) listed the average length of Ontario specimens as 13 inches (330 mm).

Golden redhorse females mature first at age 4 in Iowa and possibly later in Ontario, but dwarfed individuals in Ohio can be mature at 9.5 inches (241 mm).

The golden redhorse is apparently better adapted to river habitats than to lakes. The young often inhabit slow-moving streams with soft bottoms and this is the type of stream in which this species is found in Ontario. Trautman spoke of them as characteristic of relatively clear streams where riffles were composed of sand, gravel, boulders, and bedrock and the pools were free from heavy silt and aquatic vegetation. It is one of the few redhorses whose range does not seem to have been limited in the last decade by habitat change. They tend to be sedentary, remaining in or near the same pool, but may at times show marked downstream movements.

The food consists entirely of invertebrates sucked up out of the bottom sediments and is made up of immature insects, worms, and molluscs, such as chironomids, mayflies, caddisflies, oligochaetes, and fingernail clams.

Only as young is this species likely to be subject to significant predation. Size of adults, turbidity, and faunal composition of the habitats probably limits predation on adults to northern pike. Young and adults of this species probably do not compete for food or space with species more valued by man as significantly as was previously thought.

Hoffman (1967) listed the following parasites for this species Protozoa (3), Trematoda (4), Nematoda (3), Acanthocephala (2), leeches (1).

Relation to man In Canada this species is too limited to be of much consequence. Its size and stream habitat preclude any significant entry into the commercial catch. Although bony, Cross (1967) spoke of it as excellent food, superior to many sport fishes of Kansas in flavour and texture. Cross also stated that the golden redhorse had long supported a "gig-fishery" in which they are speared at night from a boat, thus contributing food and diversity to the recreational fishery. They are also taken on hook and line with natural bait.

Nomenclature

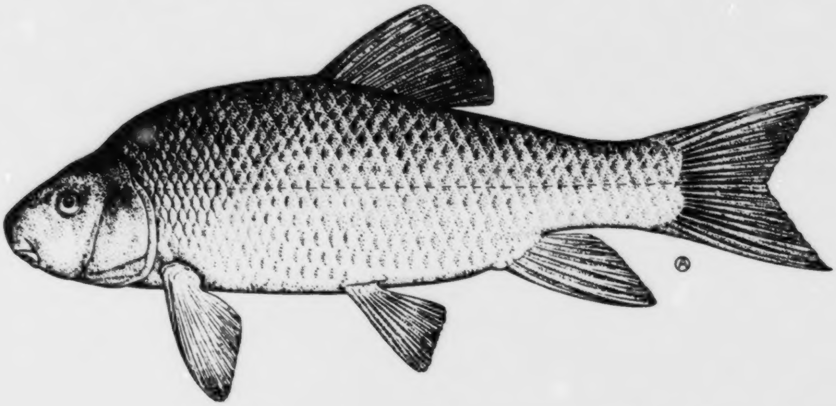
Catostomus erythrurus — Rafinesque 1818c: 354 (type locality Ohio River)
Moxostoma erythrurum (Rafinesque) — Hubbs 1930a: 6

Etymology *Moxostoma* — sucking mouth; *erythrurum* — red tailed.

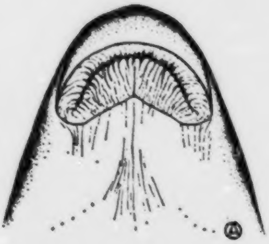
Common names Golden redhorse, golden mullet. French common name: *suceur doré*.

COPPER REDHORSE

Moxostoma hubbsi (Legendre)



Description A deeper bodied redhorse usually 15–18 inches (381–457 mm) in length. Body moderately to strongly compressed laterally, back with moderately high arch rising sharply behind head, creating a humpback appearance, tapering behind dorsal; greatest depth at dorsal origin 19.2–26.0% of total length, cross section here a deep, broad oval; caudal peduncle long and appears rather deep, but least depth only 8.0–10.3% of total length. Head naked, appears short and small on deep body, length is 14.1–17.6% of total length, deep, upper and lower surfaces meet at about 45° angle, rounded on top, very wide, interorbital width 51.6–54.2% of head length; eye moderate, diameter 40.0–45.4% of snout length, not so high on head, a little ahead of midpoint of head length; snout moderately long, 37.2–40.7% of head length, with a high, blunt point, not bulbous; mouth small, inferior, little overhung by snout, protrusible, suctorial, its width slightly less than that of head, gape reaching nostril; lips thick but not prominent, upper lip narrow with indistinct narrow plicae on inside edge, lower lip about 3 times as wide as upper, edges meet at about 105°, deeply cleft, plicae weak, long, narrow, without cross striations; no teeth in mouth, pharyngeal teeth in single row, massive, 18–21. Gill rakers medium length, widely spaced, 18 or 19 in number. Branchiostegal rays 3. Fins: dorsal 1, soft rayed, height about equal to base length which is 12.2–15.5% of total length, edge convex, 13 or 14 rays; caudal wide, moderately long, well forked, tips pointed; anal long, height 3 times base length, origin well behind insertion of dorsal, tip pointed, usually 7 rays; pelvics abdominal, origin below fifth or sixth dorsal ray, edge square, tip rounded, 9 or 10 rays; pectorals long, broad, edge square, tip a rounded point, usually 16 or 17 rays. Scales cycloid, moderately large, a little crowded forward, caudal peduncle scales 16(7-2-7), 45–47 in lateral line; lateral line complete, at midpoint of body and straight. Peritoneum silvery; intestine long, little differentiated, 4 long coils visible ventrally; no pyloric caeca; swim bladder of 3



chambers. Vertebrae 39 plus Weberian ossicles.

Nuptial tubercles on head, body, and all fins of at least the males.

Colour Dorsal surface of the body, the head, and upper sides varying from a bright coppery sheen through golden to olive, sides golden to pale olive, the ventral surface a much paler shade of the colour of sides or off-white. The fins are usually coppery to dusky.

Systematic notes This species was first referred to by Legendre in 1942 on the basis of three males and one female, 23.8–27.5 inches (605–698 mm) in total length, taken from the St. Lawrence River in the area of Lac des Deux-Montagnes near Montreal. On the advice of C. L. Hubbs, Legendre considered the specimens as examples of a species, *Catostomus carpio*, described by Cuvier and Valenciennes in 1844 on the basis of a specimen from Lake Ontario. This species had been reclassified by Jordan in 1878 as *Myxostoma carpio* (Valenciennes) Jordan, and again in 1886 as *Moxostoma valenciennesi*. Jordan and Evermann in 1896 placed it in the synonymy of *Moxostoma anisurum* (Rafinesque). Legendre however recognized the distinctness of his animals from other redhorses placed at that time in the genera *Moxostoma* and *Placopharynx* and named it *Megapharynx valenciennesi*. In 1952, he realized that the specimens represented an entirely new species and renamed it *Moxostoma hubbsi*.

Megapharynx was retained by Robins and Raney (1956) as a subgenus embracing *Moxostoma hubbsi* and *M. valenciennesi*.

Distribution (See map p. 569.) This species is restricted to the fresh waters of northeastern North America. It is presently known only from Quebec where it occurs in Lac St. Louis, Lac des Deux-Montagnes, Lac St. Pierre, the Ottawa River near Montreal, the Richelieu River, and the Yamaska River system, including Rivière Noire. It is abundant nowhere but a few specimens are seen each year.

Biology There is no published information available concerning the biology or life history of this rather rare species.

It spawns in the spring, probably in the moderate depths of the rivers. It grows to at least 27.5 inches (698 mm) in length, at which time it is likely to be 12–15 years of age.

Food of the copper redhorse will no doubt consist of a variety of invertebrates (molluscs and immature insects) which it sucks up off the bottom.

Relation to man This species is too rare to bear any relation to man. In contrast, man's activities seriously threaten the future of this species in that its total known range is subject to heavy industrial and domestic pollution.

This species is in the list of rare or endangered Canadian fishes (McAllister 1970).

Nomenclature

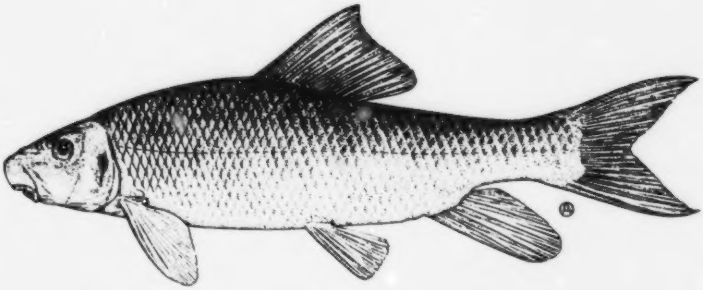
Megapharynx valenciennesi	— Legendre 1942: 229 (type locality St. Lawrence River, at Dorion, Que.)
Moxostoma hubbsi	— Legendre 1952: VI

Etymology *Moxostoma* — sucking mouth; *hubbsi* — after Dr Carl L. Hubbs, North America's foremost ichthyologist.

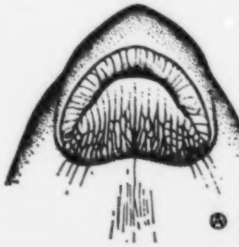
Common names Copper redhorse. French common name: *suceur cuivre* or *moxostome cuivre*.

SHORTHEAD REDHORSE

Moxostoma macrolepidotum (Lesueur)



Description A redhorse of intermediate body depth and robustness, usually 14–18 inches (356–457 mm) in length. Body laterally compressed, back with only moderate arch, tapering behind; greatest depth at origin of dorsal fin 18.0–22.9% of total length, cross section there a broad oval; caudal peduncle rather long and narrow, depth 7.2–9.3% of total length. Head naked, short, length 17.0–19.0% of total length, head angle not steep, upper and lower surface forming angle of about 35°, moderately broad, interorbital width 36.3–48.0% of head length, not deep, back little humped behind head; eye large, its diameter usually 50.0–83.3% of snout length in smaller individuals, but as low as 36.9% in large individuals, high on head, a little beyond centre of head length; snout long, 37.5–47.9% of head length, rounded, somewhat bulbous; mouth rather small, inferior, overhung by snout, protrusible, suctorial, its width much less than head width, gape barely reaching nostril; lips thick but not prominent, upper lip narrow, plicae weak, lower lip wide, 2½ times width of upper lip, edges meeting in almost straight line, cleft, plicae narrow, most obvious toward posterior, cross striations obvious; no teeth in mouth, pharyngeal teeth large. Gill rakers 22–30. Branchiostegals 3. Fins: dorsal 1, soft rayed, rather high, height exceeds base length which is 13.1–17.3% of total length, edge noticeably emarginate, rays 12–14, usually 14; caudal long, broad, deeply forked, tips pointed or upper lobe produced and pointed, lower rounded; anal long, height 2½ times base length, origin well behind insertion of dorsal fin, edge rounded, 6–8, usually 7, rays; pelvics abdominal, origin below middle of dorsal base, edge square to rounded, 8 or 9, usually 9, rays; pectorals low, long, wide, tip a rounded point, usually 17 rays. Scales cycloid, large, little crowded forward, caudal peduncle scales 11–14 but usually 12(5-2-5), 40–46 scales in lateral line; lateral line complete, at midpoint of body, straight. Peritoneum colourless to silvery; intestine long, little differentiated, 6 rounded coils, slightly to right side, obvious ventrally; no pyloric caeca; swim bladder of 3 chambers. Vertebrae usually 38 plus the Weberian ossicles.



Obvious nuptial tubercles confined on males to anal and caudal fins, minute ones on all other fins, head, and lateral and dorsal surfaces of body.

Colour Dorsal surface and upper sides brown to olive with golden, green or coppery reflections, lower sides lighter in colour with deeper bronze overtones, ventral surface milk-white to dusky yellow. Dorsal fins sometimes red, otherwise red leading tip, dark edge and dusky to orange in main area; caudal fin all bright red or wide posterior margin of red only, anal fin usually bright red to orange, others orange to yellow-pink, with red suffusion. Each upper body scale with a black crescent at base.

Systematic notes The published scientific and vernacular nomenclature of all of the redhorses is confused, but this species has been reported more often for Canada, over a longer period of time, and the names in print are consequently more confusing than some of the rarer southern Canadian forms. It has been, at various times, referred to as *M. aureolum*, *M. breviceps*, and *M. lesueurii* or *lesueuri*. Hubbs (1930a, b) stated that three species, *M. duquesnii*, *M. rubreques (=valenciennesi), and M. erythrurum*, had been previously confounded by various authors under the name *M. aureolum* and that *M. aureolum* (=*macrolepidotum*) had to be "returned to the short-headed redhorse" then known as *M. lesueurii*. Also, specimens of the species now called *M. valenciennesi* were regularly confused with and called *M. aureolum* or common redhorse. To compound the problem, the common name has shifted also. This species has for some time been known as the northern redhorse but Jenkins (1970) found that *M. breviceps*, *M. coregonus*, and *M. lachrymale* are conspecific with *M. macrolepidotum* and suggested that shorthead redhorse, the common name previously applied to *M. breviceps*, apply to the expanded species.

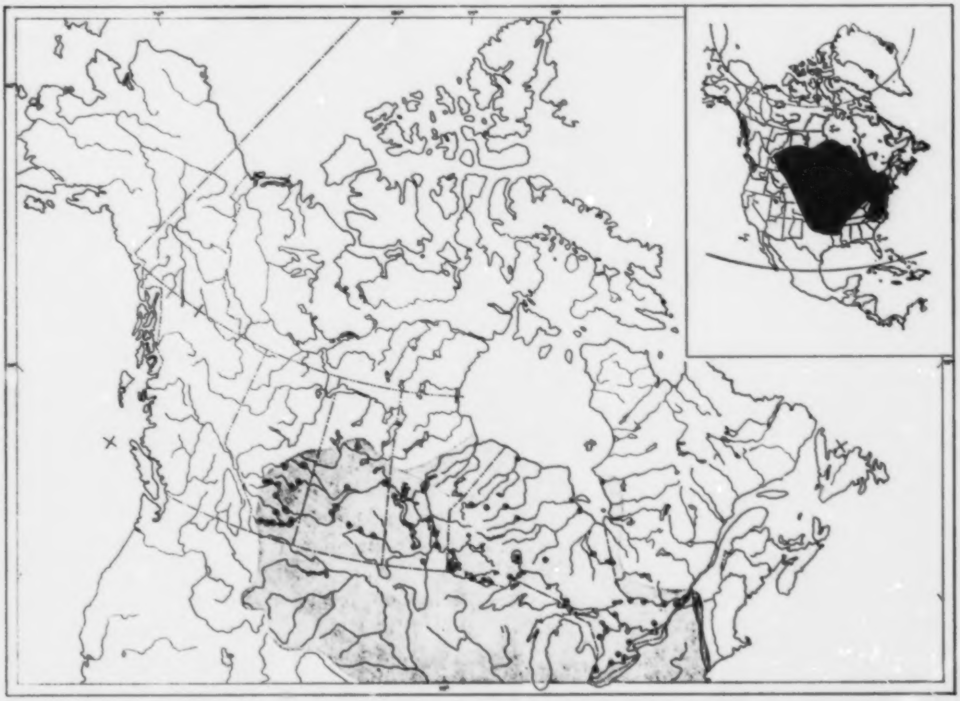
Distribution The shorthead redhorse is restricted to the fresh waters and in rare cases, brackish water, of North America and has a wider and more northern distribution than any of the other redhorses. As now expanded, it occurs from the Upper St. Lawrence River, south in the Lake Champlain drainage to the coast in New York, east of the mountains as far south as South Carolina, west across Pennsylvania and Ohio, southwest through the states from Indiana to Arkansas, the Tennessee River drainage of Alabama, west into Texas, northwest through the eastern portions of the states from Colorado to Montana, north to central Alberta, east along approximately the 55° parallel to southern Hudson Bay and the east coast of James Bay.

In Canada, it occurs in Quebec in the St. Lawrence, Richelieu–Lake Champlain, and Ottawa systems and as far north as James Bay, through the whole of Ontario, in Manitoba from the Churchill River south, from the Belanger River south in Saskatchewan and from the South Saskatchewan River south in Alberta. This redhorse occurs farther north and west in Canada than any other species of redhorse and will be the one most often encountered everywhere, especially north or west of Lake Nipigon. Vladykov (1933) said that it descends to brackish water in Hudson Bay. If this is true it is the only Canadian species of redhorse to do so.

Statements of its occurrence in the Arctic Red River (Preble 1908) and north of Great Slave Lake (Evermann and Goldsborough 1907a) are probably nomenclatorial or identification errors.

This species was first recorded in Canada by Richardson (1823) as *Catastomus Lesueurii* from Pine Island (=Cumberland) Lake, Sask.

Biology In spite of the extent of distribution of this species, it has never been looked on as valuable and consequently published accounts are usually only a statement of its presence or of its confused nomenclature. Growth data given by Reed (1962) for shorthead redhorse in the Saskatchewan River would appear to be the only Canadian biological information available, other than general statements on food and spawning, which apply to all redhorses. Most of the



following is taken from Meyer (1962), who described an Iowa population, and from the summary of information in Carlander (1969).

Characteristics of sexual maturity have been reported from June 2 (Lake Nipigon) to July 17 (Lake Abitibi) in Canada but Dymond (1926) assumed they spawned in late May in Lake Nipigon. In Iowa they spawn in late April when water temperature is 52° F (11.1° C). This species migrates, in the spring, out of larger bodies of water into smaller rivers or streams to spawn on gravelly riffles. Spawning takes place at night or in the early morning. The males arrive first, establish and defend territories, spawning lasts only a few days, no nest is built, the eggs are scattered and abandoned. Egg number in Iowa for females 12.8–18.1 inches (325–460 mm) in length and 3–6 years of age, varied from 13,500 to 27,150. Egg number has been reported as high as 29,732 in Oklahoma. For details and an illustration of the early development of young-of-the-year of this species, *see M. aureolum* in Fish (1932), and also Mansueti and Hardy (1967).

This species grows faster than other redhorses in Iowa. Trautman (1957) said young-of-the-year in October, in Ohio, were 2–4 inches (51–102 mm) in length. The relation between age, fork length, and weight in the Saskatchewan River is as follows:

Age	Length		Wt
	(inches)	*(mm)*	*(oz)*
1	–	–	–
2	3.3	84	–
3	4.4	112	2
4	10.6	269	10
5	12.0	305	12
6	–	–	–
7	13.2	335	17
8	14.0	356	22
9	14.7	373	24
10	15.4	391	30
11	15.5	394	31
12	16.5	419	40

Growth in Saskatchewan is much slower than that in Minnesota and individuals are much lighter in weight at a given age. Some may be only 1.7 inches (44 mm) in length at the beginning of the second summer and only 3 inches (77 mm) at the third. In Iowa, males of this species mature as young as 3 years of age and in South Dakota females at 2. Maturity in Saskatchewan is probably at 4 or 5 and in the Great Lakes possibly 3 or 4. Individuals in the slower-growing Canadian populations live longer as no ages greater than 9 are given for more southern populations, but maximum age in Canada is probably 12–14 years. Scott (1967) gave maximum length in Ontario as possibly over 20 inches (508 mm) and the average as 12–15 inches (305–381 mm). Trautman (1957) stated that maximum size in Ohio was 24.4 inches (620 mm) in length and a weight of 4 pounds 2 ounces, but said that Lake Erie fishermen considered 6 pounds to be maximum weight. This species, before the combination by Jenkins of the previously separate forms under the name *M. macrolepidotum*, was considered more of a lake than river form. It must now be said to inhabit the shallow, clear water of lakes or clear rivers, over bottoms of sand or gravel without heavy silt. They seem less tolerant of chemical pollution than do some sport fish but can withstand water temperatures as high as 99° F (37.2° C) (Cross 1967). It is considered now much less abundant in Ohio than it was before 1915, as a result of silting and pollution.

Like other suckers, the shorthead redhorse obtains its food by sucking up bottom material and straining from it a random variety of invertebrates. The food of this species in Lake Nipigon in the past was given by Clemens et al. (1924) as consisting of the immature forms of Ephemeroptera, Trichoptera, Chironomidae, Tipulidae, Stratiomyidae, Ostracoda, molluscs, Oligochaeta, various crustaceans, Hydracarina, and diatoms.

This species when young is probably preyed on by an assortment of piscivorous fishes. As adults, it is probably relatively free of predation except by very large northern pike and muskellunge. It is a food competitor with any other sucker with which it cohabits and probably with the lake sturgeon and other bottom feeders as well. Their small numbers in Canada reduce the threat this imposes to other species more valued by man.

Combining the lists for those forms now combined in this species given by Hoffman (1967), *(M. macrolepidotum* and *M. breviceps)*, the known parasites consist of Protozoa (1), Trematoda (1), Nematoda (1), and Crustacea (2).

Relation to man This species and all other redhorses in Canada are too poorly known to even estimate their relation to man in their ecological role. This species has always constituted a minor part of the commercial landings of the Great Lakes and other Canadian fresh waters. Nash (1908) suggested that persistent commercial netting in Ontario during the spawning season had made it comparatively scarce by 1908. Since the shorthead redhorse is probably the most abundant, it obviously constitutes the bulk of the proportion of redhorses which are marketed as suckers or mullets. The flesh is sweet and flaky but the numerous bones bothersome. This species was probably utilized as human food to a far greater extent in the past as their spawning migrations made them readily accessible. Jordan and Evermann (1908) said shorthead redhorse were held in high esteem by farmers who snared, seined, and trapped great numbers of them in the spring and salted them away for winter. Attempts in Ontario to market and serve this species as mullet were never very successful. The Department of Home Economics of the University of Manitoba in 1939 investigated the potential of the commercial and home canning of this species. However, no apparent increase in home canning or any commercial venture resulted from this study (Lantz 1948).

Migdalski (1962) said this species was marketed in larger cities and brought better prices than the white sucker. He also said that there is enough angling pressure on the redhorse to rate it as a sport fish and that many are taken during spring spawning migrations using worms, grubs, grasshoppers, or small pieces of meat as bait.

Nomenclature

A true picture of the Canadian synonymy of this species is difficult as a result of the confusion of the many forms of redhorses until very recent times. What seems like unnecessary repetition of synonyms is necessary where authors have used names for separate species that are now combined under *macrolepidotum* and for authors who used one name one year and another name later.

Catostomus macrolepidotum — LeSueur 1817d: 94 (type locality Delaware River)
Catastomus Lesueurii — Richardson 1823: 721
Cyprinus (Catastomus) Sueurii — Richardson 1836: 118
Cyprinus (Catastomus) aureolus (LeSueur) — Richardson 1836: 119
Catastomus aureolus — Forelle 1857: 281
Catastomus Sueuri — Small 1865: 30
Moxostoma aureolum (LeSueur) — Eigenmann 1895: 108
Moxostoma lesueuri (Richardson) — Jordan and Evermann 1896–1900: 194
Moxostoma breviceps (Cope) — Jordan and Evermann 1896–1900: 196
Moxostoma aureolum LeSueur — Halkett 1913: 60
Moxostoma macrolepidotum LeSueur — Halkett 1913: 60
Moxostoma lesueuri Richardson — Halkett 1913: 60
Moxostoma breviceps Cope — Halkett 1913: 60
Moxostoma Aureoleum — Lower 1915: 43
Moxostoma aureolum (LeSueur) — Dymond 1922: 63
Moxostoma lesueurii (Richardson) — Dymond 1939: 21
Moxostoma aureolum (LeSueur) — Dymond 1947: 15

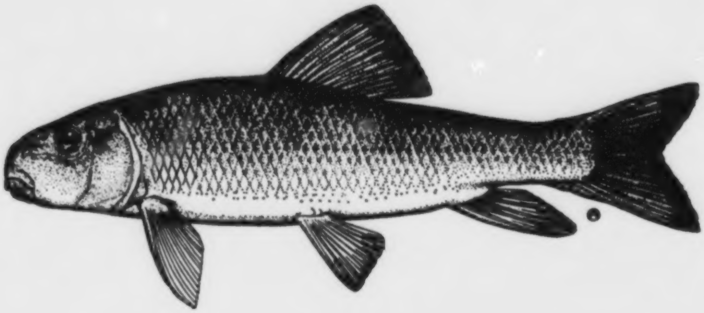
Etymology *Moxostoma* — sucking mouth; *macrolepidotum* — large scales.

Common names Shorthead redhorse, northern redhorse, northern shorthead redhorse, short-headed red-horse, common redhorse, short-headed mullet, common mullet, red sucker. French common name: *suceur rouge*.

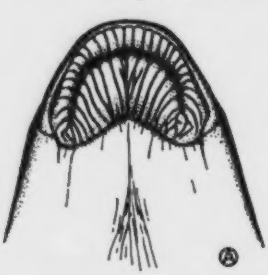
Until recently, this species has been generally known as northern redhorse. Jenkins' 1970 decision that several previously separate forms should be combined under *M. macrolepidotum* required a new common name for the expanded species and he selected shorthead redhorse.

GREATER REDHORSE

Moxostoma valenciennesi Jordan



Description (Based on the single available study specimen and the literature). A large, somewhat laterally compressed sucker, usually 15–18 inches (381–457 mm) in length. Back with shallow arch to dorsal fin, tapering behind; greatest depth at dorsal origin, about 24% of total length; cross section there a deep, broad oval; caudal peduncle rather long and narrow, its depth about 8–9% of total length. Head massive and long, its length about 19–20% of total length, upper surface not steep, broad, interorbital width about 47% of head length, and deep, upper surface rounded; eye small, diameter about 27–28% of snout length, rather high on head and at midpoint of head length or slightly beyond; snout long, 53% of head length, almost square and vertical at tip; mouth inferior but not overhung by snout; protrusible, suctorial, its width very little less than snout width, gape barely reaching to nostril; lips very thick, more conspicuous than in many other redhorses, upper lip wide, plicae coarse and conspicuous even on anterior edge; lower lip wide, 2½ times upper lip, edges meeting at an angle of 90°–110°, deeply cleft, plicae coarse, deep, no cross striations; no teeth in mouth, pharyngeal teeth heavy but compressed and comb-like. Gill rakers about 27–31 in number. Branchiostegal rays 3. Fins: dorsal 1, soft rayed, height exceeds base length, which is about 14–15% of total length, leading edge straight to definitely rounded, usually 13 rays; caudal long, moderately forked, tips blunt points, or upper produced and lower rounded; anal long, height almost 3 times base length, origin well behind insertion of dorsal fin, tip a rounded point, usually 7 rays; pelvics abdominal, low, wide, origin below fourth dorsal ray, edge square, usually 9 rays; pectorals low, long, moderately wide, tip pointed, usually 16–18 rays. Scales cycloid, large, not crowded anteriorly, caudal peduncle scales 16(7-2-7), about 42–45 scales in lateral line; lateral line complete, at midpoint of body and straight. Peritoneum colourless to black; intestine long, little differentiated, 5–7 rounded coils obvious ventrally; no pyloric caeca; swim bladder of 3 chambers. Vertebrae usually 38–40, plus the Weberian ossicles.



Nuptial tubercles on males confined to anal and caudal fins.

Colour Dorsal surface and upper sides olive-green with bronze reflections, sides paler and more golden, ventral surface golden or milk-white. Dorsal, caudal and anal fins deep red, lighter in young individuals, anterior tip of dorsal fin white to pink, anterior rays of pelvic and pectoral fins whitish, remainder of pelvic fins pale red, and of pectoral fins olive (Trautman 1957). Each scale base with a definite dark crescent.

Systematic notes As is the case with the other redhorses, an analysis of early records of this species in Canada and the United States is confounded by the confusion of the various forms. Records prior to 1930 are doubtful, and often the common name used then is more trustworthy than the scientific name applied then to this species. The most recent synonym applied to this form was *M. rubreques* but certain past records of *M. aureolum* are considered to apply to this form. Hubbs (1930a) said that three species, *M. duquesnii*, *M. rubreques (=valenciennesi)* and *M. erythrurum* had been previously confounded by various authors under the name *M. aureolum*, and that *M. aureolum (=macrolepidotum)* had to be "returned to the short-headed redhorse" then known as *M. lesueurii*. Notes of the late Dr J. R. Dymond show that confusion was still great in the 1930's as he had then been prepared to rather indiscriminately reduce most previous Canadian records of *aureolum* (such as Nash 1908; Evermann and Latimer 1910; and Dymond 1922) to the synonymy of *M. rubreques* on Hubbs' suggestion that it was this species which was the commonest in the Great Lakes and known by the fishermen as *the* redhorse. Also, there was confusion between the form now bearing this name and the copper redhorse, prior to the clarification by Legendre (1942, 1943, 1952).

Distribution (*See* map p. 569.) The greater redhorse is restricted to the fresh waters of central and eastern North America and primarily the Upper Mississippi and Great Lakes–St. Lawrence systems. It occurs from the St. Lawrence (downstream from Montreal) south into New York in the Lake Champlain system, southwest, just south of the Great Lakes, through northwestern Ohio, northern Indiana and Illinois, northwest through Wisconsin and Minnesota to eastern North Dakota and east through southern Ontario.

Recent identifications, of previously unidentified material, by R. Jenkins has extended our knowledge of the distribution of this species in Canada. In Canada it occurs in Quebec in the St. Lawrence River and tributaries downstream to Lac St. Pierre, the Richelieu–Champlain system, the Ottawa River, and tributaries of lakes Ontario (the type locality), Erie, St. Clair, and Huron, north at least to the Spanish River near Sudbury. Many published suggestions of its possible occurrence in Lake of the Woods would seem to be in error. In Ontario this species is often found with *M. macrolepidotum* in the south and with that species and *M. anisurum* farther north.

Biology Apparently less is known of the biology of this species than any of the redhorses other than the copper redhorse. There are only general comments published on it from Canadian waters and Carlander's usually very useful handbook (1969) does not even have a section on this species.

It is doubtless a spring-to-summer spawner, probably May to early July in Canada, and is said to spawn in moderately rapid streams. Trautman (1957) listed young-of-the-year in Ohio as 1.5–3.0 inches (38–76 mm) in length. He said the largest Ohio specimen was 24.5 inches (622 mm) long and weighed an estimated 3–5 pounds. This is the largest of the redhorses in Canadian waters. Hubbs (1930a) gave maximum weight as 12–16 pounds. Dymond et al. (1929) quoted fishermen as saying Lake Ontario specimens reached 13 and 16 pounds, but the identities may have been in error. Scott (1967) said that individuals weighing over 10 pounds were caught in the past in Lake Ontario but that average weight was approximately 2 pounds. Specimens from near Montreal reported by Vladykov (1942) were 15.8–19.6 inches (401–499 mm) in length. A specimen taken in the Richelieu River in July 1970, which was 23.1 inches (587 mm) in length but only 6 pounds 1 ounce in weight, approximates the maximum given by Trautman.

The habitat of this form was said by Trautman to be large streams having clear water and bottoms of clean sand, gravel, or boulders. This species probably occurs, in limited numbers, in the Great Lakes themselves near the mouths of tributary streams. These characteristics pertain in the eastern and northern streams of Ontario where this species is taken but not in the Grand River (Lake Erie) or tributaries of the Niagara River which are softer bottomed and muddy. Trautman attributed their reduction in number and in area occupied, to increased siltation and pollution. Consequently, this species is similarly in danger over most of its range in Canada.

The food of this species is, in all likelihood, the same range of invertebrates, immature insects, worms and molluscs, as that utilized by the other redhorses.

Parasites, probably of this species, listed by Hoffman (1967) under *M. rubreques,* were: Trematoda (1), Cestoda (2), Acanthocephala (3), Crustacea (1).

Relation to man With virtually no knowledge of its biology, its ecological role can only be guessed as of minimal importance to man. In the streams it inhabits it probably competes with few important forms. In the St. Lawrence, Niagara, and other large Canadian rivers it may compete with important invertebrate-eating bottom-feeders such as the lake sturgeon. In Canada its stream habitat, relatively low abundance, and low market acceptance make its contribution to commercial catches extremely low or nil.

Nomenclature

As a result of the past confusion in the forms of redhorses and the consequent clouded nomenclature, a true picture of the Canadian synonymy is virtually impossible.

Catostomus carpio — Cuvier and Valenciennes 1844: 457 (type locality Lake Ontario)
Moxostoma valenciennesi — Jordan 1886: 73
Moxostoma anisurum — Günther 1868: 20
Moxostoma aureolum — Nash 1908: 32
Moxostoma aureolum LeSueur — Halkett 1913: 60
Moxostoma aureolum (LeSueur) — Dymond 1922: 63
Moxostoma rubreques (Hubbs) — Hubbs and Brown 1929: 21

Etymology *Moxostoma* — sucking mouth; *valenciennesi* — after Achille Valenciennes, the famous French naturalist who first described this species on the basis of a specimen from Lake Ontario.

Common names Greater redhorse, common redhorse, redhorse. French common name: *suceur jaune*.

Suggested Reading – Catostomidae

Bailey, M. M. 1969. Age, growth, and maturity of the longnose sucker, *Catostomus catostomus*, of western Lake Superior. J. Fish. Res. Bd. Canada 26: 1289–1299.

Bowman, M. L. 1970. Life history of the black redhorse, *Moxostoma duquesnei* (Lesueur), in Missouri. Trans. Amer. Fish. Soc. 99: 546–559.

Brown, C. J. D., and R. J. Graham. 1954. Observations on the longnose sucker in Yellowstone Lake. Trans. Amer. Fish. Soc. 83: 38–46.

Campbell, R. S. MS 1935. A study of the common sucker, *Catostomus commersoni* (Lacépède), of Waskesiu Lake. M.A. Thesis. Dep. Biol., Univ. Saskatchewan, Saskatoon, Sask. 48 p.

Geen, G. H., T. G. Northcote, G. F. Hartman, and C. C. Lindsey. 1966. Life histories of two species of catostomid fishes in Sixteenmile Lake, British Columbia, with particular reference to inlet spawning. J. Fish. Res. Bd. Canada 23: 1761–1788.

Harris, R. H. D. 1962. Growth and reproduction of the longnose sucker, *Catostomus catostomus* (Forster), in Great Slave Lake. J. Fish. Res. Bd. Canada 19: 113–126.

Hauser, W. J. 1969. Life history of the mountain sucker, *Catostomus platyrhynchus*, in Montana. Trans. Amer. Fish. Soc. 98: 209–215.

Hubbs, C. L. 1930. Materials for a revision of the catostomid fishes of eastern North America. Misc. Publ. Mus. Zool. Univ. Mich. 20: 47 p.

Jenkins, R. E. MS 1970. Systematic studies of the catostomid fish tribe Moxostomatini. Ph.D. Thesis. Cornell Univ., Ithaca, N.Y. 800 p.

Johnson, R. P. 1963. Studies on the life history and ecology of the bigmouth buffalo, *Ictiobus cyprinellus* (Valenciennes). J. Fish. Res. Bd. Canada 20: 1397–1429.

Jordan, D. S. 1878. A synopsis of the family Catostomidae, p. 97–230. *In* Contributions to North American ichthyology; based primarily on the collections of the United States National Museum. Bull. U.S. Nat. Mus. 12.

Meyer, W. H. 1962. Life history of three species of redhorse (*Moxostoma*) in the Des Moines River, Iowa. Trans. Amer. Fish. Soc. 91: 412–419.

Raney, E. C., and E. A. Lachner. 1946. Age, growth and habits of the hog sucker, *Hypentelium nigricans* (LeSueur), in New York. Amer. Midland Natur. 36: 76–86.

Robins, C. R., and E. C. Raney. 1956. Studies of the catostomid fishes of the genus *Moxostoma*, with descriptions of two new species. Mem. Agr. Exp. Sta. Ithaca 343: 56 p.

Smith, G. R. 1966. Distribution and evolution of the North American catostomid fishes of the subgenus *Pantosteus*, genus *Catostomus*. Misc. Publ. Mus. Zool. Univ. Mich. 129: 132 p. + 1 pl.

Stewart, N. H. 1926. Development, growth, and food habits of the white sucker, *Catostomus commersonii* LeSueur. Bull. Bur. Fish. 42: 147–184.

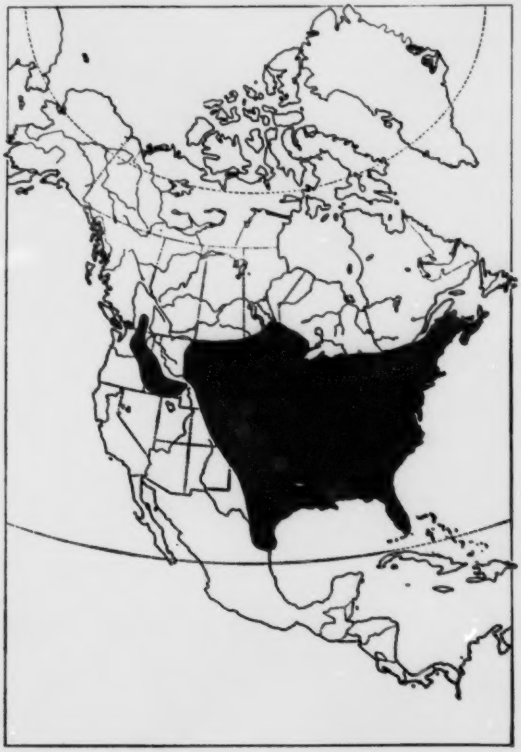
CATFISH FAMILY — Ictaluridae

Small to large fishes with the body naked and rotund forward, but laterally compressed beyond the dorsal fin. The head is large, flattened, and possessing several pairs of whisker-like barbels. Teeth of jaws are small and cardiform. Dorsal fin, with a serrate spine, forward and rounded; pectoral fins low and armed with a serrate spine; pelvic fins abdominal; anal fin long; caudal fin forked, square, or round; a free or an adnate, adipose fin present. The fin spines of some of the smaller madtoms equipped with a groove and venom sac.

Characteristic of temperate to subtropical larger rivers, lakes, and slow-moving waters of North America and Central America.

A family of about 6 genera and 44 species restricted to the New World. Known from the Eocene to Recent.

There are a number of fascinating characteristics associated with this family, such as: the intimate connection of the swim bladder with the Weberian ossicles and their role in the reception and production of sound; the role in orientation, schooling, breeding, and feeding of a highly developed sense of "taste" centred in sensory cells on the body and concentrated on the barbels (*see* Brown 1957a, b; Bardach et al. 1967; Kleerekoper 1969); the nocturnal habit; the problems of age analysis in scaleless fishes (*see* Lewis 1949; Sneed 1951; Appelget and Smith 1951; and Marzolf 1955); venom associated with the fin spines (*see* Reed 1907); and their major commercial, angling, and pond cultural value (*see* Kendall 1910; Maloy and Willoughby 1967; and Kennamer undated).



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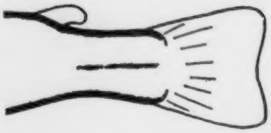
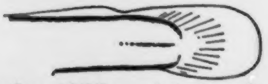


1 Adipose fin short, fleshy, free at posterior end, obviously well separated from the caudal fin; tail round, squared, or forked; can be up to 24 inches (610 mm) in length 2

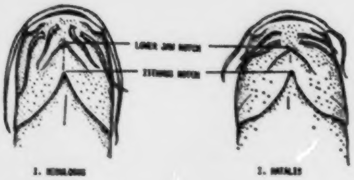


Adipose fin long, low, a simple, ridgelike extension of the caudal fin, with or without a notch marking point of connection; tail round or squared; never over 12 inches (305 mm) in length 5

2 Caudal fin deeply forked; obvious bony ridge connecting skull and origin of dorsal; barbels at corners of mouth more than 3 times as long as those near nostrils .... CHANNEL CATFISH, *Ictalurus punctatus* (p. 604)

Caudal fin round, square, or slightly indented, never deeply forked; area between head and origin of dorsal compressible, no bony ridge; barbels at corners of mouth about twice as long as those near nostrils 3

3 Upper barbels grey to yellow, lower barbels yellow to white; depressed anal fin overlaps anterior rays of caudal fin; distance from isthmus notch to lower jaw notch much less than distance from lower jaw notch to tip of lower jaw .... YELLOW BULLHEAD, *Ictalurus natalis* (p. 595)

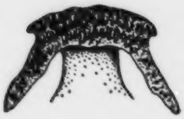


Upper and lower barbels dark brown to black; anal fin does not reach anterior rays of caudal fin; distance between isthmus and lower jaw notches almost equal to distance from lower jaw notch to tip of lower jaw 4

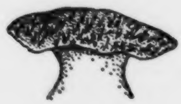
4 Barbs on trailing edge of pectoral spines strong, even near tip, and catch fingernail when moved toward tip; anal rays (all rudiments included) usually 21–24; dorsal interray membranes not noticeably darkened .... BROWN BULLHEAD, *Ictalurus nebulosus* (p. 598)

Barbs on trailing edge of pectoral spines weak or absent, especially near tip; if present near base, barbs usually catch fingernail only when moved toward base; anal rays (all rudiments included) usually 17–21; dorsal interray membranes usually noticeably darkened .... BLACK BULLHEAD, *Ictalurus melas* (p. 591)

5 Dorsal surface more or less flat to origin of adipose fin; greatest depth (at origin of dorsal fin), into body length (to base of caudal rays) over 6 times; strongly countershaded, dark above, yellow to white below, small, white to yellow spot at dorsal insertion; premaxillary tooth patch with lateral extensions; can be to 12 inches (305 mm) in length .... STONECAT, *Noturus flavus* (p. 611)



Dorsal surface rises to obvious apex at dorsal origin, greatest depth into body length (to base of caudal rays) about 4 times; generally dark, or pale with dark saddles and bars; premaxillary tooth patch without lateral extensions; never over 6 inches (152 mm) in length 6

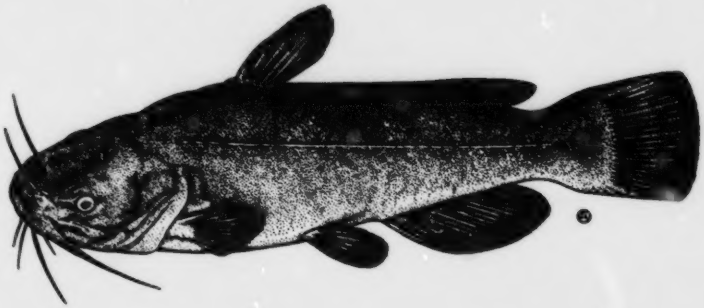


6 Body pale, conspicuously marked with dark saddles and bars; ventral surface white to yellowish; caudal fin outlined in black and white; very strong barbs on pectoral spines; dorsal spine about 66% of maximum height of dorsal fin .... BRINDLED MADTOM, *Noturus miurus* (p. 619)

Body generally dark, ventral surface dusky, often 3 noticeable dark horizontal lines behind dorsal fin; myotomes often obvious; caudal fin dusky; no barbs on pectoral spines; dorsal spine not more than 50% maximum height of dorsal fin .... TADPOLE MADTOM, *Noturus gyrinus* (p. 615)

BLACK BULLHEAD

Ictalurus melas (Rafinesque)



Description This smaller bullhead is usually only 5–7 inches (127–178 mm) in length. The following description is based on specimens from Manitoba and Saskatchewan. A rather massive body, heavy, rounded forward, somewhat potbellied, greatest depth at dorsal fin origin 19.2–23.6% of total length, angle from tip of snout to dorsal fin origin steep; body behind dorsal fin laterally compressed; caudal peduncle short, rather deep, depth 8.6–10.5% of total length. Head massive, long, its length 24.5–28.5% of total length, very wide, interorbital width 48.1–57.1% of head length, naked, rounded on top; eye small, its diameter 10.4–14.7% of head length, very round, slightly protruding; snout moderately long, 36.6–44.6% of head length, broad and shallowly rounded on top; paired nostrils on each side widely separated, the posterior one of each pair opening through expanded base of a moderately long, flattened snout barbel; mouth terminal, horizontal, short but wide, maxillary short, gape reaching only half way to eye, lips fleshy but not prominent, 1 pair of long, flattened maxillary barbels, the longest of 4 pairs of barbels, arise from upper lip at angle of mouth, reach opercular opening; fine, cardiform teeth in several irregular rows on dentary, premaxillary and on a rounded patch on the last pharyngobranchial; under surface of head very broad, flat, 2 pairs of barbels just behind lower jaw, inner pair shorter. Gill rakers moderately long, pointed, 14–20 in number, ranging from 10–14 on lower limb and 4–6 on the upper limb, widely spaced. Branchiostegal rays usually 8 or 9 on each side. Fins: dorsal 1, ahead of midpoint of body, snout to dorsal origin 32.4–35.1% of total length, soft rayed but first is a stout spine (modified soft ray), spine equal to or less than ½ height of fin, spine curved slightly, barbs on posterior edge very weak or absent, height of fin at least twice length of base, which is 6.8–9.2% of total length, edge of fin rounded, one spine and 5 or 6 soft rays; adipose long, fleshy, little turned up, free at posterior end but attached for much of its length, fin length 12.5–19.3% of total length; caudal with expanded base, but only moderately broad, posterior margin truncate to emarginate; anal base long, 12.2–20.4% of total length, greatest height almost equal to base length, posterior edge rounded, 15–19 rays (not including 2 anterior rudiments); pelvics abdominal, low, origin behind insertion of dorsal fin, broad, rounded, tips overlapping origin of anal fin in males, usually 8 rays; pectorals rather high, broad, rounded, anterior heavy spine about ½ length

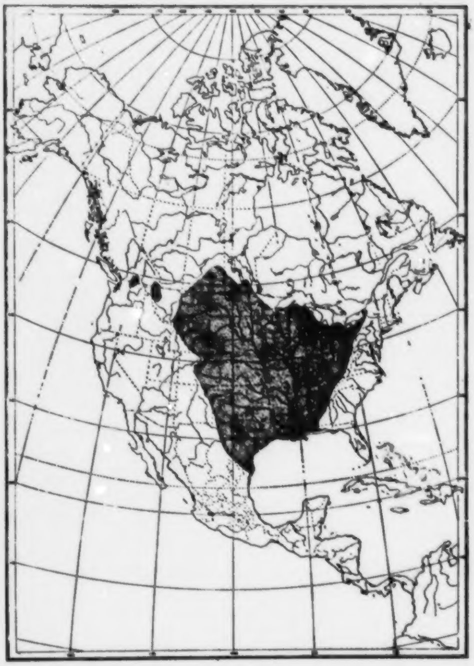
of fin, barbs on posterior surface of spine absent or extremely weak, one spine and 8 soft rays; skin truly naked but well supplied with "taste" receptors, no scales on any part of body; lateral line complete, almost straight and at midpoint of body. Peritoneum heavily speckled with black, intestine well differentiated, coiled, no pyloric caeca. Swim bladder silvery, with thick walls. Vertebrae usually 34 or 35, plus Weberian ossicles.

No nuptial tubercles.

Colour Dorsal surface of head, body and upper sides dark brown, olive to black, sides a lustrous green to gold, ventral surface yellow, muddy white to milk-white, extending up at base of caudal fin as a pale bar; barbels grey, black, or black spotted; dorsal, caudal, and paired fins dusky with black edges and dark black interray membranes contrasting with lighter rays. Anal fin with basal third lighter, membranes of distal third black, giving a bicoloured appearance. Sides beyond dorsal fin show dark vertically angled lines which are separations between muscle blocks. Spawning males jet black with bright yellow or white belly; young black with white belly.

Systematic notes This species is often considered as consisting of two subspecies, the northern black bullhead *I. m. melas*, which would be the form in Canada, and *I. m. catulus* in the Gulf states and northern Mexico.

Distribution This species is restricted to the fresh waters of North America. The northeastern limit of the black bullhead would appear to be St. Lawrence River tributaries in New York in the vicinity of the Oswegatchie River. Its range extends south along the southern shore of Lake Ontario, west of the mountains to the Tennessee River and Mobile Bay drainages in Alabama, west through the Gulf states, through Texas and extreme northern Mexico, north through the eastern parts of the states from New Mexico to Montana, and to Saskatchewan, east through Manitoba, through the Great Lakes states below Lake Superior at the level of Green Bay, Lake Michigan, to extreme southwestern Ontario. Introduced widely elsewhere including Connecticut, California, Arizona, and Washington State. The introductions in the Columbia River in Washington, resulted in natural spread to Oregon, Idaho (?), and British Columbia.



In Canada, the native range of the black bullhead is limited to Lake Erie and its western tributaries and the Qu'Appelle–Souris–Assiniboine systems in southern Saskatchewan and Manitoba. It is present in Osoyoos Lake (Okanagan–Columbia system), British Columbia, probably as a natural immigrant resulting from introductions in the Columbia River in Washington State.

This species is rare in Canada and the ROM research collection contains no representatives from Ontario. This is strange considering an apparent increase in numbers in Ohio and areas to the south. When small, it is difficult to separate this species from *I. nebulosus*. This, and the fact that young brown bullheads (1–4 inches or 25–102 mm) are pitch black have resulted in many misidentifications and erroneous distribution records, such as that of Meek and Clarke (1902) for Gull and Muskoka lakes, Ont., and that of Evermann and Latimer (1910) for Lake of the Woods, Ont.

Biology Nothing is known of the biology of this species in Canada. The black bullhead is usually considered a spring spawner, and the time most often quoted is May and June, or when the water temperature reaches 69.8° F (21° C). However, spawning time must be longer since in one year in Iowa (Forney 1955) the first spent female was taken June 26, the first young were taken July 7 and the last ripe female was captured August 6. Forney estimated peak of spawning activity as early July. Spawning takes place in areas of moderate to heavy submerged vegetation. In shallow water, the female excavates a nest, the diameter of which is approximately equal to her length, by pushing away gravel and fanning away silt and debris. Prior to spawning, the pair butt one another, and each slides its barbels over the body of the other. Egg deposition follows a head to tail clasping in which the caudal fin of the male is wrapped around the head of the female (Wallace 1967). Intermittent spawning acts, as many as five in an hour, alternate with periods when the female fans, with her fins, those eggs already laid. After the first day both sexes fan and guard the mass of eggs. Usually about 200 eggs are laid but the ovaries contain 3000–4000 prior to spawning. Other estimates from Iowa ran as high as 6820 eggs. The eggs are covered with a gelatinous coat, are somewhat adhesive, pale cream in colour, and about 3 mm in diameter. When temperatures are high, eggs hatch in as little as 5 days. Newly hatched young school in a loose sphere and associate closely with a guarding parent for several weeks. Soon after the size of the young exceeds 1 inch (25 mm) the parents abandon them. The reactions involved in this schooling and association were described in detail by Bowen (1931, 1932).

Growth of the young is highly variable but in a year of fast growth in Iowa mean total length increased during the period from July 1 to August 20, from 1.07 to 3.0 inches (26–76 mm).

The following relation between age (as calculated by soft fin ray sections) and total length for a North Dakota population is from Carlander 1969:

Age	Total length	
	(inches)	*(mm)*
0 (Aug.)	3.0	76
1	4.3–4.6	109–117
2	4.5–6.7	114–170
3	7.4–10.2	188–259
4	10.1–12.4	257–315

Growth is extremely variable year to year, and place to place. Stunting occurs. A maximum size of 12.4 inches (315 mm) at age 4 is indicated. However, ages 8 and 9 are also quoted for this species in Iowa at total lengths between 10.4–13.8 inches (264–351 mm). The largest black bullhead listed by Carlander was 14.9 inches (378 mm) in length and possibly weighed 2 pounds. Trautman (1957) listed maximum size as 16.8 inches (427 mm) in length and a weight of 2 pounds 12 ounces, but said adults were usually 4.5–12.0 inches (144–305 mm) in length and weighed 1–15 ounces. Walden (1964) mentioned a sporting-tackle record fish of 24 inches (610 mm), 8 pounds weight, from Lake Waccabuc, N.Y., in 1951. Scott (1967) reported that Ontario specimens averaged less than 8 inches (203 mm) in length.

The habitat of this species is usually considered to be lower sections of small- to medium-sized streams of low gradient, ponds, and backwaters of larger rivers and silty, soft-bottomed areas of lakes or impoundments. It does not inhabit the areas in which brown and yellow bullheads usually occur but seems to replace those species there if the habitat deteriorates. The black bullhead is apparently also more tolerant of pollutants than the other two species. This species can withstand extremely high water temperatures. Upper lethal temperature of individuals acclimated at 73.4° F (23° C) was 95° F (35° C), (Black 1953). Contrary to many species, this fish is apparently increasing in number and in area occupied in the northern United States but would still appear to be rare in Canada.

The adults of this species, like those of other bullheads, are almost entirely nocturnal. The young apparently feed most actively just before dawn and again just after dark, the adults during the night. Activity was described in detail by Darnell and Meierotto (1965). Food is sought along the bottom by means of the tastebuds on the barbels and possibly those on the body. The usual items of food are immature insects, clams, snails, crustaceans, plant material, leeches, and fishes. Immature insects and molluscs alternate dominance from place to place and from time to time. Fishes are of minor importance but common shiners and perch have been reported. The young eat immature insects, crustaceans, and leeches.

Predation on the black bullhead, even as young, is apparently very low. This may result in part from their habitat, the type of fishes associated with them there, and protection afforded by the spines and nocturnal habit.

The black bullhead is a competitor of sunfishes and some other bottom feeders but utilizes molluscs which many of the other species do not.

Parasites listed by Hoffman (1967) were: Protozoa (5), Trematoda (28), Cestoda (5), Nematoda (8), Acanthocephala (3), leeches (4), Crustacea (7).

This species hybridizes with the brown bullhead in Ohio waters of Lake Erie.

Relation to man This species is presently of little or no importance to man in Canada. It probably makes up a small proportion of the commercial fishes marketed as catfish or bullheads in the United States. Greeley (1929) quoted Fowler as saying they were abundant in Lake Erie, and were frequently marketed in and around Erie, Pa. This species is an important sport fish in all of the midwest states of the United States. It also is a good farm pond species there and if fed daily grows to 6 inches and 1 pound weight in a year and will easily yield 200 pounds of fish per acre. The flesh is said to be tastier than that of the brown bullhead.

Nomenclature

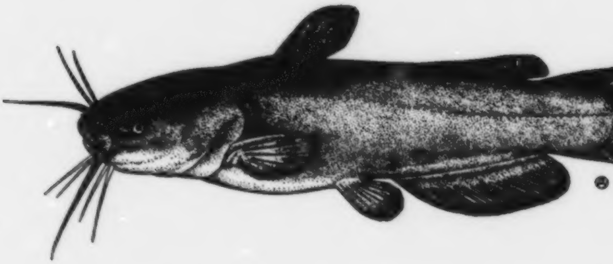
Silurus Melas	— Rafinesque 1820d: 51 (type locality Ohio River)
Ameiurus melas (Rafinesque)	— Jordan and Evermann 1896–1900: 141
? *Ameiurus vulgaris*	— Thompson 1898: 214
Ameiurus melas melas (Rafinesque)	— Hubbs and Brown 1929: 42
Ictalurus melas melas (Rafinesque)	— Taylor 1954: 44

Etymology *Ictalurus* — fish cat; *melas* — black.

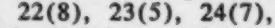
Common names Black bullhead, black catfish, yellow belly bullhead, hornedpout. French common name: *barbotte noire*.

YELLOW BULLHEAD

Ictalurus natalis (Lesueur)



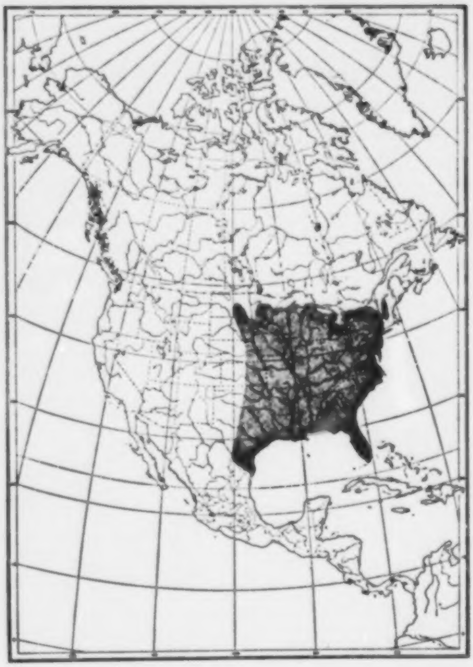
Description This is a medium-sized fish, usually 8–12 inches (203–305 mm) in length. It has a more rotund, robust body than the brown bullhead, greatest body depth, at dorsal fin origin, 19.2–25.1% of total length, laterally compressed behind the anal fin; caudal peduncle short and deep, depth 10.0–11.9% of total length. Head heavy, long, its length 22.1–27.1% of total length, very wide, interorbital width 38.2–54.9% of head length, naked, rounded on top; eye small, its diameter 9.4–20.5% of head length, round, protruding; snout moderately long, 36.2–43.4% of head length, broad and rounded, paired nostrils widely separated, posterior pair opening through expanded base of long snout barbels; mouth terminal, moderately long, and wide, gape reaching almost to eye; upper jaw slightly longer than lower; lips thick but not prominent; 1 pair of flattened maxillary barbels, the longest of the 4 pairs of barbels, reach to or just past end of operculum; fine, cardiform teeth in an oval pad on premaxillary, in several rows on lower jaw and on 2 pairs of rounded patches on the last pharyngobranchial bones; undersurface of head broad, flat, with 2 pairs of white to pale yellow barbels, inner pair shorter. Gill rakers moderately long, well spaced, 14–16 in number (usually 10+4). Branchiostegal rays usually 8 or 9. Fins: dorsal 1, ahead of midpoint of body (snout to dorsal origin is 29.1–34.4% of total length), soft rayed with first modified ray a stout spine, spine about ¾ height of fin, spine straight, barbs on posterior edge very weak, height of fin longer than base which is 6.8–8.7% of total length, edge of fin a rounded point, 1 spine and 6 soft rays; adipose long, fleshy, little turned up, free length equal to or greater than base, fin length 10.3–15.9% of total length; caudal rounded, with broad base; anal base long, 20.2–27.4% of total length, depressed fin touches or overlaps base of caudal fin, greatest height just over ½ base length, rounded, but anterior and posterior rays almost equal in length, rays (not counting 2 anterior rudiments) for 22 specimens from 10 localities, 22(8), 23(5), 24(7), 25(2); pelvics abdominal, low, overlapping base of anal fin in some, 8 rays; pectorals broad, rounded, spine more than ½ length of fin, barbs on posterior edge of spine strong in young, weaker in large individuals, 1 spine and 7 or 8 soft rays, almost always 8; skin naked and supposedly thinner than that of the black and brown bullheads, no scales on any part of body; lateral line complete, nearly straight, at midpoint of body. Peritoneum grey, not heavily speckled. Intestine well differentiated, coiled, no pyloric caeca. Swim



bladder heartshaped, silvery, with thick walls. Vertebrae usually 38 plus Weberian ossicles.

Colour Back, top of head, and upper sides olive through brown to almost black depending on habitat, sides lighter, yellow-brown to yellow, never mottled, ventral surface from chin to pelvic fins yellow to white; upper barbels light to dark brown, chin barbels yellow through buff to pale pink, no black pigment or spots on barbels; fins dusky to pale brown, some pigment on membranes, bases darker, anal fin sometimes with vague dark bar through centre, tip of adipose sometimes pale. Young usually dark brown to black, with white under head and belly, lower barbels white.

Systematic notes Radforth (1944) suggested Canadian populations represent postglacial entry from the Mississippi River and from the eastern seaboard. There is little in the present morphological data to strengthen this idea other than a slight tendency toward one more anal ray in the Lake Erie area, 22(5), 23(2), 24(3), 25(2), as compared with the St. Lawrence River area, 22(3), 23(3), 24(4). However, available material is insufficient for a definite decision. Anal ray numbers were rechecked by dissection and x-ray since 26 or more (counting rudiments ?) is often used as a distinguishing characteristic for this species in the United States. Also some of the material reported in Hubbs and Brown (1929) from Dedrick's Creek, near Port Rowan, Ont., was reexamined in 1952 and said to have "long anal fins which, without dissection, have at least 26 rays." None of the Canadian material presently examined, including another collection from near Port Rowan, had more than 25 rays (not counting 2 anterior rudiments, visible only by dissection or x-ray). This species is often considered to consist of two subspecies, *I. n. natalis* in the Great Lakes and Mississippi River watersheds, *I. n. erebennus* coastwise from New Jersey to Florida and west to Alabama. The yellow bullhead is frequently mistaken in Canada for the commoner and more generally distributed brown bullhead.



Distribution The yellow bullhead is restricted to the fresh waters of eastern and central North America. It occurs from the Connecticut River in New Hampshire (introduced) south along the coast to Florida, west through the Gulf states to southern Texas and northern Mexico, north through the eastern half of the states from Oklahoma to North Dakota, east across central Minnesota to southern Lake Huron, through extreme southern Ontario and into New York. Introduced in California and probably elsewhere.

In Canada it occurs only in Ontario. Its range there extends from the extreme Upper St. Lawrence River and its tributaries, including the Gananoque and the Rideau River systems (more common), lakes Ontario (rare), Erie, St. Clair, and Huron (south), and their tributaries. It may be more abundant and more generally distributed in eastern Ontario than in southwest Ontario. The species is poorly represented in research collections and should be watched for during fishing activities.

The first record of this species in Canada is probably that of Reighard (1894) for Lake St. Clair.

Biology There is virtually no published information on this species in Canada other than notes by Toner (1937, 1943) and Curran et al. (1947). Other than age and growth data, very little is available from anywhere and much of the following was taken from Carlander (1969). Spawning takes place in the spring for a period of about 2 weeks, usually in late May to early June, possibly earlier than other bullheads in the same area. One or both sexes build a nest varying from the usual shallow depression to a burrow 2 feet deep, often under a stream bank or near the protection of stones or stumps. Batches of creamy white, glutinous eggs, usually 300–700, are laid and fertilized during a spawning clasp. Total egg number has been calculated at 1652–4270 in females 6 ounces to 1 pound 4 ounces in weight (approximately 9–13 inches or 230–330 mm in length). Eggs hatch in 5–10 days. The male guards the nest and the brood of young until they are about 2 inches (51 mm) in length. Fish (1932) and Mansueti and Hardy (1967) gave details of the early development of young. Young-of-the-year in October in Ohio are usually 2.0–3.5 inches (51–89 mm) in length, and growth in Michigan during the first month was 0.6 mm per day. The following age–total length, and length–weight relations (a composite of several northern United States populations), give a crude approximation for Canadian populations.

Age	Total length		Wt
	(inches)	*(mm)*	*(oz)*
1	1.2–2.6	30–66	0.06
2	7.1–9.6	180–244	3.58–5.75
3	7.6–10.8	193–274	3.58–10.05
4	8.9–11.6	226–295	5.75–12.20

The above data are taken from the following sources: Length and weight, age 1, from Carlander (1969); length, ages 2, 3, 4, for Wisconsin, from Carlander (1969); weight, ages 2, 3, 4, for Ohio, from Langlois (1936).

Trautman (1957) said that average size of adults was 5.5–15.0 inches (140–381 mm) length, and 2 ounces to 2 pounds weight. Scott (1967) said they attain an average size of ½–1 pound in Ontario. Trautman cited the largest specimen as 18.3 inches (465 mm) and 3 pounds 10 ounces. Maximum age would appear to be 6 or 7 years. Sexual maturity is probably attained at 2–3 years of age.

The habitat of the yellow bullhead is usually in areas of very heavy aquatic vegetation in shallow, clear-water parts of bays of lakes, small shallow lakes, ponds, and slow-moving streams, with various bottom types from muck to gravel. This species is apparently more capable of withstanding adverse conditions than black or brown bullheads but removal of stumps, logs, or vegetation leads to a decrease in number.

This species consumes a wide variety of food which it searches out along the bottom at night, largely with its barbels. It is considered a scavenger. Food ranges from offal, crustaceans (from entomostracans to crayfish), immature aquatic insects, molluscs and, to a minor degree, fishes.

Catfishes are in general afforded some protection against predation by their nocturnal habit, their spines, and their discriminant senses of taste and olfaction (Todd et al. 1967). Catfishes have, however, been recorded in the stomach contents of basses, walleyes, other catfishes, snapping turtles, water snakes, and as the host of lampreys. The yellow bullhead has been recorded from the stomach of a moccasin, *Agkistrodon piscivorus*, by Yerger (1953).

This species probably competes indirectly with a number of other bottom feeders. Catfishes are often accused of being heavy predators on the eggs of other, more valuable, species, but this would appear to be untrue.

The parasites of this species were listed by Hoffman (1967) as follows: trematodes (21), cestodes (6), nematodes (7), acanthocephalans (3), leeches (1), molluscs (1), crustaceans (5), and linguatulans (1).

Relation to man In certain areas of the United States the yellow bullhead may make up a small portion of those species marketed simply as bullheads. It is unlikely that they do so in Canada. They are taken by anglers in the United States using live bait. Anglers in eastern Ontario probably take them at times thinking they are the much commoner brown bullhead. The flesh is whiter than that of the brown bullhead and is delicious.

Nomenclature

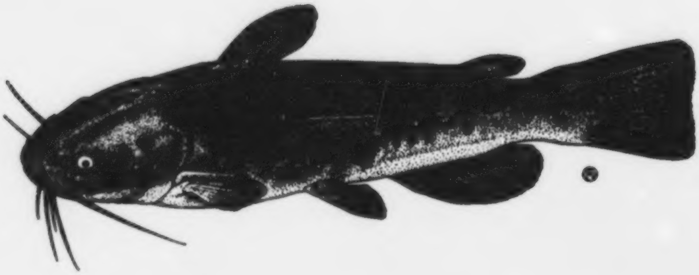
Pimelodus natalis	— LeSueur 1819: 154 (type locality North America)
? *Silurus (Pimelodus) coenosus* (Richardson)	— Richardson 1836: 132
? *Pimelodus coenosus* Richardson	— D'Urban 1859: 270
Amiurus natalis	— Günther 1864: 101
Ameiurus natalis (LeSueur)	— Reighard 1894: 21
Ictalurus natalis (LeSueur)	— Taylor 1954: 44

Etymology *Ictalurus* — fish cat; *natalis* — having large nates or buttocks.

Common names Yellow bullhead, northern yellow bullhead, yellow catfish, bullhead. French common name: *barbotte jaune*.

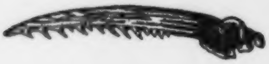
BROWN BULLHEAD

Ictalurus nebulosus (Lesueur)



Description This moderate-sized bullhead is usually 8–14 inches (203–356 mm) long. In the following description percentages are for populations from New Brunswick to Ontario only but meristics include, where possible, specimens as far west as British Columbia. Body massive, rounded, and heavy forward, usually less potbellied than yellow bullhead, greatest body depth at origin of dorsal fin, 17.7-26.3% of total length; angle from tip of snout to origin of dorsal fin less steep; body behind dorsal fin laterally compressed; caudal peduncle moderately deep, depth 8.1–9.9% of total length, and long.

Head massive, moderately long, its length 22.6–26.3% of total length, very wide, interorbital width 45.2–53.2% of head length, head naked, shallowly rounded to slightly concave on top; eye small but at times larger than eye of yellow bullhead, diameter 10.0–18.7% of head length, round, slightly protruding; snout moderately long, 35.6–44.2% of head length, broad, shallowly rounded; paired nostrils widely separated, posterior one of each pair opening through base of moderately long, flattened snout barbel; mouth terminal but upper jaw slightly longer than lower jaw, mouth horizontal, not long but wide, maxillary not long, gape extending to posterior nostril, lips fleshy but not prominent; 1 pair of long flattened maxillary barbels, the longest of 4 pairs of barbels, reaching to end of operculum or base of pectoral fin; fine, cardiform teeth in several irregular rows on lower jaw, premaxillary, and on 2 pairs of rounded patches on the last pharyngobranchials; undersurface of head very broad, flat, with 2 pairs of rather heavy, flattened barbels, inner pair shorter. Gill rakers moderately long, pointed, usually 9 on upper limb and 4 or 5 on lower limb, widely spaced. Branchiostegal rays usually 9, 9, but can be 8, 8 or several unequal combinations from 8 to 10 on each side. Fins: dorsal 1, ahead of midpoint of body, snout to dorsal origin 30.4–34.3% of total length, soft rayed but first is a stout spine (modified soft ray), spines in dorsal and pectorals can be "locked" in erect position by an interesting arrangement of bones and muscles, spine a little more than ½ height of fin, slightly curved barbs on posterior surface very weak or absent, height of fin about twice base length which is 6.6–9.3% of total length, edge of fin rounded, almost always 1 spine and 6(57) soft rays, but rarely 1 spine and 7(1) soft rays; adipose long, fleshy, somewhat curved upward, free length usually exceeds base, fin length 10.7–14.7% of total length; caudal with squarish expanded base, moderately broad, edge truncate to emarginate, tips never pointed, principal (or segmented) rays usually 23(14) but sometimes 22(3); anal base long, 17.5–20.7% of total length, greatest height just over ½ base length, rounded but middle rays longer than posterior rays, rays 18(21), 19(6), 20(29), or 21(3), (not including 2 anterior rudiments); pelvics abdominal, low, origin behind dorsal insertion, broad, rounded, tips not overlapping origin of anal, 8 rays; pectorals rather high, broad, rounded, anterior heavy spine almost as long as fin, barbs (usually 4–8) large, recurved, rays usually 8 but sometimes 7(2) or 9(7). Skin truly naked of scales but well supplied with taste glands; lateral line complete, almost straight and at midpoint of body. Peritoneum silvery to grey, not noticeably speckled with black; intestine well differentiated, coiled, no pyloric caeca. Heart-shaped swim bladder silvery with thick walls. Vertebrae usually 34–39 plus Weberian ossicles.



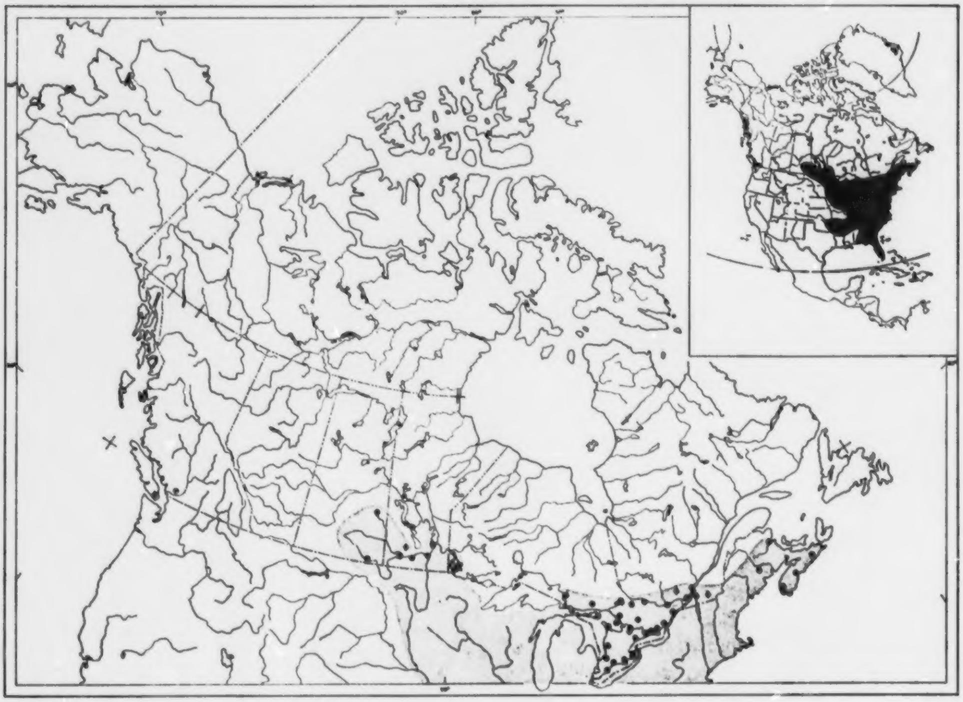
No nuptial tubercles.

Colour Dorsal surface of head and body and upper sides yellow-brown, olive, grey to almost blue-black, sides of lighter-coloured individuals often mottled with vague brown blotches, lower sides over pelvic fins dirty white, undersurface of body ahead of pelvic fins pale yellow to white; all barbels dark brown to nearly black, except sometimes base of chin barbels pale yellow to white; fins same colour as body but paler, some darker pigment on ray membranes.

The chromatophore system of this species and the effect of habitat on colour have been extensively studied (*see* Rasquin 1949).

Systematic notes The brown bullhead is often considered as two subspecies – *I. n. nebulosus*, in Canada and south in the United States to a line northwestward from Virginia, through the northern part of the Ohio valley, to North Dakota, and *I. n. marmoratus*, the form occurring to the south (Hubbs and Lagler 1958).

The only meristic trends suggested in the limited Canadian material examined are



fewer vertebrae in the west (34 or 35) as compared to Ontario and east (36–39); and for pectoral rays to be lower (7 or 8) northward to the east, and west of southern Ontario (8 or 9). Much more data would be required to verify these suggested trends.

Distribution The native distribution of this species is restricted to the fresh waters and, rarely, brackish waters of eastern and central North America. It occurs from the Maritime Provinces of Canada south along the coast to Florida, west to central Alabama, northern Mississippi and Louisiana, to eastern Texas and Oklahoma, northeast through the states from eastern Missouri to central North Dakota (rare) and to southern Saskatchewan, east through southern Manitoba, south of Lake Superior, and across Ontario and Quebec at about the level of Lake Nipissing. It has been extensively introduced westward including Idaho and California. It was released in Germany in the early 1900's and has been widely moved from there to England, many European countries, and the USSR.

In Canada it occurs from the mainland of Nova Scotia, through New Brunswick, the southern tip of Quebec, north to Mattawa but primarily in the eastern townships, across southern Ontario at the level of Lake Nipissing, to the south shore of Lake Superior, and again in the Lake of the Woods area, west through southern Manitoba and as far west as the Whitesand–Assiniboine system of southeast Saskatchewan. It occurs also, as a result of introductions, in British Columbia in the lower Fraser River and in several lakes on lower Vancouver Island, between Victoria and Nanaimo.

The brown bullhead is primarily a freshwater fish but McKenzie (1959) recorded it from 40 feet deep in water of a salinity between 8 and 15‰, in the estuary of the Miramichi River, N.B.

Biology The brown bullhead is another of the species well represented in Canada for which there is no detailed life history information. *See* Emig (1966) and Carlander (1969) for summaries of life history information.

A great deal has been written on the breeding and brood-guarding habits of this species, possibly beginning with Eycleshymer in 1901, and was largely summarized by Breder and Rosen (1966).

The brown bullhead spawns in the late spring and summer, probably May and June in Canada, when water temperature reaches 70° F (21.1° C). In the south, spawning may continue through September and individuals may spawn more than once in one year. One or both sexes clear a shallow nest, the diameter of which is just in excess of body length, in a bottom of mud or sand or among the roots of aquatic vegetation, usually near the protection of a stump, rock, or tree. At times nest burrows are built. Brown bullheads will also nest under boards, in hollow stumps, and even inside automobile tires nailed on docks as boat fenders. The water over these nesting sites can be as shallow as 6 inches (152 mm) or as deep as several feet and the nests are usually found around the shores of lakes, or in coves, bays, or creek mouths.

Spawning apparently takes place in the daytime. The male and female caress one another with their barbels, circle about the nest or remain quietly over it. Eventually they settle over the nest, bodies in contact, but facing in opposite directions, and spawning takes place. No mating clasp is mentioned for this species. A large number of spawning acts take place with an increasing number of eggs released at each. Sometimes one or both parents eat some or all of the eggs. The eggs are pale cream in colour, coated with a gelatinous mucus, adhesive and about 3 mm in diameter. Females from 8–13 inches (203–230 mm) length may have from 2000–13,000 eggs in the ovaries. The eggs in the nest are cared for by one or both parents. They are fanned with the paired fins, moved, stirred with the barbels and fin spines, and at times picked up in the mouth and ejected. This fanning and manipulation is necessary, possibly as a result of the gelatinous coat on the eggs, as bullhead eggs will not hatch without it, even in water with more than adequate oxygen. Eggs take 6–9 days to hatch at 69°–74° F (20.6°–23.3° C). Fish (1932) and Mansueti and Hardy (1967) gave details of egg, larval, and juvenile development. At hatching the young are about 6 mm in length, yellow, and somewhat transparent but begin to darken on the second day. The yolk sac is too large to enable them to swim and they lie on their sides in the nest until about the seventh day. They then begin to swim and feed actively. The young, whose shape and pitch-black colour make them resemble tadpoles, are shepherded about for several weeks in a loose sphere by one or both of the parents until they are about 2 inches (51 mm) in length. Then the guarding and the school break down and the individuals disperse. Two individual broods in Lake Danford, Que., were netted and counted. They contained 610 and 778 young.

Growth is moderately rapid and by October the young in Ohio are 2.0–4.8 inches (51–122 mm) in length. There are no published age–length relations for Canadian populations, but those given below for Little Lake Butte des Mortes in northern Wisconsin (Priegel 1966) may approximate those of Canadian populations.

Age	Mean TL	
	(inches)	*(mm)*
2	6.0	152
3	7.6	193
4	9.5	241
5	10.5	267

The weight–metric fork length regression for Lake Jesse, N.S., was given by Smith (1939) as log W= −5.166+3.125 log FL and specimens were 3.2–9.3 inches (81–237 mm) fork length and an average weight of about 3 ounces. Langlois (1936) gave weight in Ohio fish ponds as varying from 0.01–38.75 ounces for fish from 0.8–16.9 inches (22–431 mm) total length. The greatest number of individuals were between 9.9 and 11.8 inches (252–301 mm) long and weighed 8.3–12.9 ounces.

Sexual maturity is usually attained by age 3 by females 8–13 inches (203–330 mm) in length, and males slightly smaller. Maximum age would appear to be 6–8 years. In Canada adults are usually 8–14 inches (203–356 mm) in total length and weigh ¾–1 pound. Trautman (1957) listed maximum size in Ohio as 18.8 inches (478 mm) and 3 pounds 14 ounces weight. However, Carlander (1969) cited individuals as large as 20.9 inches (532 mm) in Florida. They have been reported by anglers as large as 6–8 pounds in the Napanee River, Ont. In unsuitable habitats, such as cold elevated lakes, they grow poorly and stunted populations result.

Brown bullheads usually occur near or on the bottom in shallow, warmwater situations, in ponds, small lakes, shallow bays of larger lakes, and larger, slow-moving streams with abundant aquatic vegetation, and sand to mud bottoms. They are sometimes found as deep as 40 feet. They are very tolerant of conditions of temperature, oxygen, and pollution which might be limiting for other species. They can survive temperatures as high as 97° F (36.1° C). Their upper lethal temperature, under experimental conditions, varied from 83.5°–99.5° F (28.6°–37.5° C), with acclimation temperatures from 42.8°–96.8° F (6°–36° C). They survive high carbon dioxide and low oxygen concentrations. In winter, they can live at 0.2 ppm oxygen. As a result of this tolerance and their bottom habit, they are most difficult to eradicate chemically. It has been reported that they burrow into the bottom mud to avoid adverse conditions. They seem particularly resistant to domestic and industrial pollution as in many heavily polluted streams near Montreal they were the only species present.

This species, like the other bullheads, feeds on or near the bottom, mainly at night, and food is searched out largely by means of the barbels, and by the senses of "taste" and "smell". The adults are truly omnivorous in that their food is composed of offal, waste, molluscs, immature insects, terrestrial insects, leeches, crustaceans (crayfish and plankton), worms, algae, plant material, fishes, and fish eggs. The young (30–60 mm) feed primarily on chironomid larvae, cladocerans, ostracods, amphipods, bugs, and mayflies. As they increase in size, cladocerans are replaced by an increase in hemipterans and ostracods and by newly hatched fishes (Keast and Webb 1966), but small fishes and eggs are taken at times. *See* Raney and Webster (1940) for a detailed analysis of food of young in New York.

Brown bullheads, especially the young, are apparently eaten by a variety of predatory fishes, at times out of proportion to their numbers relative to other available forage fishes. Species listed as predators are chain pickerel, northern pike, muskellunge, walleye, and sauger. This predation probably takes smaller fishes for which the spines do not provide maximum protection. Individuals of various species, including a muskellunge, have been reported with the spines of a consumed bullhead protruding through the body to the exterior, the wounds healing around the spines, and the predator still apparently healthy. The protective and survival value of the spines to individuals and to the species might be in doubt.

Brown bullheads probably compete quantitatively for bottom organisms with a wide variety of fishes. Their nocturnal feeding habits, and their tactile searching makes the competition indirect but no less effective. This species has definitely been reported to have eaten the eggs of at least cisco, herring, and lake trout. However, many authors feel they are not egg predators to the extent that it has been assumed. Martin (1957) said that brown bullheads were the chief predators on lake trout eggs in the lakes of Algonquin Park, Ont. He mentioned having seen hundreds feeding on lake trout eggs in one lake. This was, however, "when low lake levels had forced the trout to spawn on rubble," an apparently unsatisfactory situation "which offered little protection to the eggs."

The parasites of this species, from various localities in Canada, have been listed by Bangham and his coauthors (1936, 1939, 1940, 1941, 1946, 1954, 1955). The summary list given by Hoffman (1967) is as follows: Protozoa (4), Trematoda (36), Cestoda (8), Nematoda (16), Acanthocephala (8), leeches (5), Mollusca (1), Crustacea (9). Ali and Hanyu (1964) reported the development of double and triple lenses in the eyes of brown bullheads in Quebec, possibly resulting from the presence of an eye fluke, *Diplostomum* sp.

Brown bullheads hybridize with black bullheads in Lake Erie and other localities where they occur together in habitats marginal to one or both species.

Relation to man This species is not one of the more popular freshwater fishes in Canada. Some people even claim their appearance to be distasteful. In spite of this it is a species of some considerable commercial and recreational importance. The flesh is firm, reddish to pink in colour, and delicious cooked in a variety of ways or hot-smoked. Brown bullheads readily take a variety of live or dead natural bait or dough-balls, and are rather easily caught, sometimes in large numbers. This species is not covered by season, size, or bag limit regulations and it often provides the angler with enjoyment and food prior to the opening of the season for more favoured sport fish. Best angling success is usually obtained by still fishing with worms or minnows usually just as darkness falls.

They are a very suitable pond culture species and to the south yield very high production. Standing crops have been calculated as high as 486.6 fish per acre or 132 pounds per acre in California. The only available standing crop figures for natural waters in Canada are those of Smith (1938, 1939) for Nova Scotia lakes. These ranged from 6.7–38.0 fish per acre and up to 5.5 pounds per acre. Some shallow areas of Ontario lakes must produce much more than this.

The commercial catch in Canada is mostly in Ontario where they are marketed simply as bullheads. Some yellow bullheads may enter into the catch but they would be negligible compared to the contribution of brown bullheads. The commercial catch in Ontario in 1966 was 347,721 pounds with a value of $59,734.66. The catch came, in descending order of contribution, from southern inland lakes, Lake Ontario, northern inland lakes, Lake St. Clair, and Lake Erie. The Bay of Quinte (Lake Ontario), St. Lawrence River and Rideau Lakes areas are the major commercial grounds. The catch and value have been higher in some past years.

Nomenclature

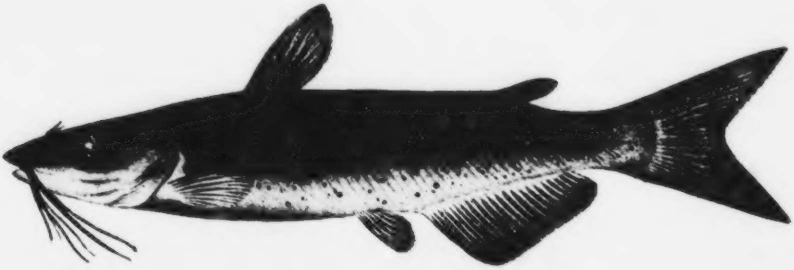
Pimelodus nebulosus	— LeSueur 1819: 149 (type locality Delaware River at Philadelphia, Pa., although often given as Lake Ontario)
? *Silurus Felis* ?	— Richardson 1823: 723
Silurus (Pimelodus) coenosus (Richardson)	— Richardson 1836: 132
? *Silurus (Pimelodus) nigrescens* (LeSueur)	— Richardson 1836: 134
Pimelodus vulgaris	— Thompson 1842: 138
Pimelodus felis	— Agassiz 1850: 281
Pimelodus catus	— Perley 1852: 195
Pimelodus atrarius	— Small 1865: 27
Amiurus nebulosus LeSueur	— Wright 1892: 429
Amiurus vulgaris	— Wright 1892: 442
Amiurus catus Gill	— Cox 1896b: 64
Ameiurus lacustris (Walbaum)	— Evermann and Goldsborough 1907a: 92
Ameiurus vulgaris (Thompson)	— Evermann and Goldsborough 1907a: 92
Ameiurus nebulosus (LeSueur)	— Evermann and Goldsborough 1907a: 92
Ictalurus nebulosus nebulosus (LeSueur)	— Taylor 1954: 43

Etymology *Ictalurus* — fish cat; *nebulosus* — clouded, in relation to mottled and grey colouring.

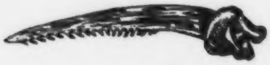
Common names Brown bullhead, northern brown bullhead, marbled bullhead, common bullhead, bullhead, brown catfish, common catfish, catfish, mudcat, hornpout, horned pout, minister. French common name: *barbotte brune*.

CHANNEL CATFISH

Ictalurus punctatus (Rafinesque)



Description This species is the largest of the catfishes in Canada and adults are usually 14–21 inches (356–533 mm) in length and 2–4 pounds in weight. In the following description percentages are for Ontario specimens only but meristic values include specimens from Manitoba. Body massive but less potbellied, less rounded forward, moderately deep, greatest depth, at origin of dorsal fin, is 14.2–22.7% of total length; angle of head from tip of snout to dorsal fin origin shallow; body behind pelvic fins laterally compressed, deeper here than other catfishes, caudal peduncle moderately long, deep, least depth 7.0–8.5% of total length. Head massive, long, its length 19.6–24.6% of total length, very wide, wider in males than females, interorbital width 39.1–52.3% of head length, head naked, flat to shallowly rounded on top; eye not so small as in other catfishes, diameter 10.8–19.3% of head length, round, slightly protruding, high on head, ahead of midpoint of head; snout long, 35.6–49.2% of head length, broad, flat to shallowly rounded on top; paired nostrils separated, posterior one of each pair opening through base of short snout barbel; mouth inferior, definitely overhung by somewhat papillate upper lip, mouth short but wide, maxillary short, gape reaching only to anterior nostril; 1 pair of long, flattened, wide, maxillary barbels, the longest and largest of 4 pairs of barbels, arises at angle of mouth and extends past head length; fine, cardiform teeth in several irregular rows on dentary, premaxillary, and on pairs of rounded patches on the pharyngobranchial bones; undersurface of head very broad, flat, chin with 2 pairs of wide, flattened barbels, outer pair twice length of inner pair. Gill rakers long, widely spaced, slender, pointed, 14–18, usually 9–12 on lower limbs, 5 or 6 on upper limb. Branchiostegal rays 8 or 9 according to McAllister (1968), but varied from 7,7 to 8,8 in material examined. Fins: dorsal 1, ahead of midpoint of body, snout to dorsal origin 28.0–31.1% of total length, soft rayed but first is stout spine (modified soft ray), spine a little less than ⅔ height of fin, almost straight, no barbs on posterior surface, height of fin a little less than twice base length which is 6.4—8.3% of total length, tip usually pointed, edge almost square, one spine and 6 rays; adipose fleshy, long, length 7.3–12.3% of total length, little turned up, free length about equal to base length; caudal with less noticeably expanded base, but very broad and deeply forked, the tips pointed (the only catfish in Canada with a forked tail); anal base long, 19.6–24.9% of total length, edge square to rounded but anterior rays longest, greatest height about ½ base length, rays 23(2)–26(1), usually 24(15) or 25(9) (excluding 2 anterior rudiments); pelvics abdominal, low, origin behind insertion of dorsal fin, broad, edge square to rounded, tips overlap origin of anal fin, 8 rays; pectorals low, broad, tips rather pointed, edge square to slightly rounded, anterior heavy spine at least ¾ length of fin, barbs on posterior edge of spine strong, one spine and 8 or 9 rays, usually 9(20 of 22); skin naked of scales but well supplied with chemoreceptors or "taste" receptors, especially on barbels; lateral line complete, straight and near midpoint of body. Peritoneum speckled with black, intestine well differentiated, coiled; no pyloric caeca. Swim bladder heart-shaped, thick walled, silvery. Vertebrae usually 42–44 plus Weberian ossicles.

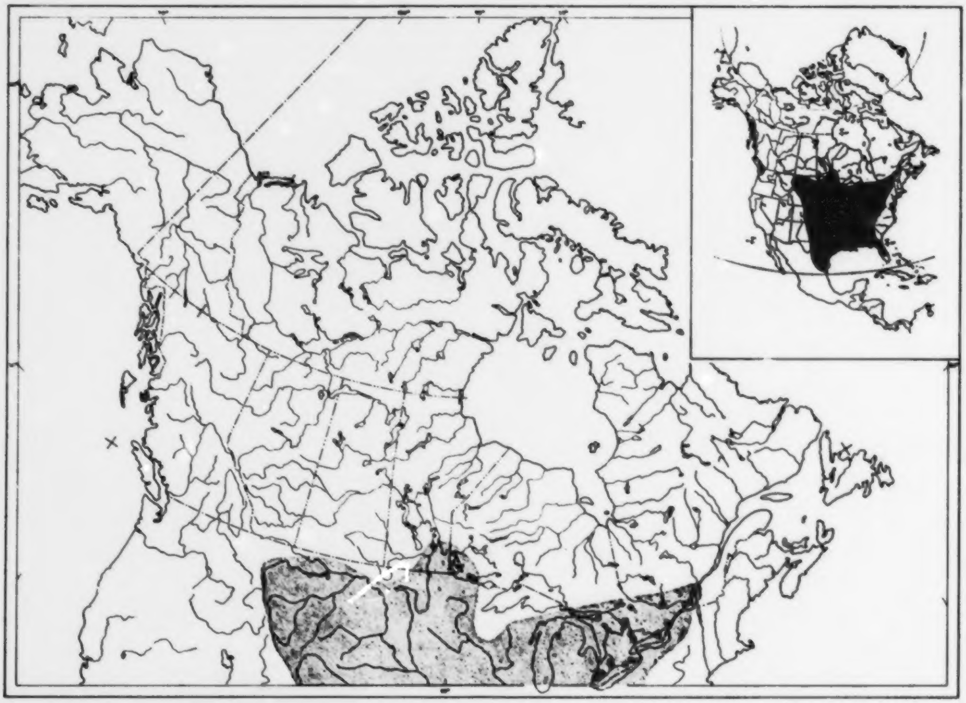


No nuptial tubercles but head of male becomes swollen above and behind the eyes at spawning time.

Colour Individuals less than 12–14 inches (305–356 mm) pale blue to pale olive with silvery overcast, ventral surface silver-white to milk-white, sides with varying number of olive to almost black spots of varying size but smaller than pupil. Adults with dorsal surface of head and back, and upper sides steel-blue to grey, lower sides lighter, ventral surface of head, and body to pelvic fins, dirty white to silver-white. Fins not noticeably different from adjacent body, nor membranes contrasting. Barbels darkly coloured but without spots, base of inner chin barbels often colourless. Males at breeding time often brighter blue than otherwise. There are albino races in the southern part of the range.

Systematic notes There was, for many years, considerable taxonomic and nomenclatural confusion associated with what we now recognize as this species. Differences in shape and colour, now known to be associated with sex, size, season, and locality were once construed to be indicative of several different species or subspecies. Many names such as *lacustris*, *punctatus*, *robustus*, *meridionalis*, and *anguilla*, in the genera *Amiurus*, *Ameiurus*, *Ictalurus*, *Villarius* and *Haustor*, were applied over the range to forms now considered to be this species. At one time, Canadian populations in the Great Lakes were referred to as both *Ictalurus punctatus* (Rafinesque) — the spotted catfish, the name applied to it then where it occurred elsewhere in Canada, and *Ameiurus lacustris* (Walbaum) — the Great Lake catfish, which was thought to occur only in the lower Great Lakes. Later this species in Canada was referred to as *Ictalurus l. lacustris*, the northern counterpart of *I. l. punctatus* of the Mississippi River and south. Much of the name problem arose as a result of a confusion in the early literature between the channel catfish and the burbot. This was largely resolved by Speirs (1952). More recently, populations in Canada, the Great Lakes, and the Mississippi River system have been referred to as *I. punctatus punctatus* with the idea that there are possibly several distinct subspecies in the far south.

There remains the problem of Richardson's (1836) name, *Silurus borealis*. The fish described from Pine Island Lake (=Cumberland Lake, Sask.) certainly seems to be the channel catfish, but that species does not, at present, occur in the same watershed (Saskatchewan River) nor within 350 miles of that location. No species of catfish now occurs any closer than the black bullhead in the Whitesand River, Sask., about 200 miles to the south. Whether Richardson's animal was a burbot and the description is wrong, or his specimen was correct and his locality data



wrong, is impossible to say.

Material examined indicates little in the way of trends in meristic variability within Canada. The lowest anal ray count (23) was from Sparrow Lake, Muskoka District, Ont., and the highest (26) from Lake Erie with Quebec and Manitoba counts intermediate.

Distribution This species is restricted to the fresh waters, and to a limited extent brackish waters, of east and central North America. Vladykov (1949c) cited a specimen from the St. Lawrence River at St. Roch des Aulnaies, an area usually thought brackish to salt water. The native range would appear to be from the St. Lawrence and its tributaries in Quebec, south, west of the Appalachian Mountains, to southern Georgia and central Florida (Lake Okeechobee), west through the Gulf states to eastern Texas and northern Mexico (as far south as the Rio Pánuco system), northwest through the eastern part of the states from New Mexico to Montana, east to the Red River system in Manitoba, southwestern Ontario, southern Minnesota, Wisconsin, and Michigan and through Ontario and Quebec at the level of Lake Nipissing.

It has been so widely introduced in the United States, both east and west (Connecticut, California, Utah, etc.) outside this native range as to be found nearly everywhere in the United States.

In Canada the channel catfish occurs in the St. Lawrence River and its tributaries, from a point about 45 miles below Quebec City (mouth of Rivière Ouelle) in southern Quebec, the Ottawa River and tributaries, all the Great Lakes except Superior, all of Ontario, north to a line from the Ottawa River through Lake Nipissing and the French River to Lake Superior, and in the Nelson River system of extreme western Ontario and Manitoba, north to the southern portion of lakes Winnipeg and Manitoba. Many United States publications give the southern parts of the Prairie Provinces of Canada as the northern limit of distribution but, in spite of extensive collecting, it is presently known to occur in only Manitoba. *See* Willock's 1969 discussion of Richardson's 1836 record and Stegner's 1955 record of its occurrence in Saskatchewan.

Biology This fish is locally abundant in certain parts of Canada but poorly known. There is very little published information on its biology in Canada other than that of Magnin and Beaulieu (1966). In contrast, there is a voluminous literature from the United States. Most of the following was derived from Magnin and Beaulieu, and summaries of United States literature by Miller (1966) and Carlander (1969).

Channel catfish spawn in late spring or summer when water temperatures reach a point between 75° and 85° F (23.9°–29.5° C) with 80° F (26.7° C) the apparent optimum. Channel catfish kept in a power plant effluent pond at a constant 80° F (26.7° C) and fed on pellets, spawned April 14, 2 months ahead of those in the rivers nearby. Depending on habitat, the spawners may or may not migrate into rivers or moving water at spawning time. Spawning takes place in secluded, semidark nests built by the male, in holes, undercut banks, log jams, or rocks. They will not spawn in transparent ponds unless something is provided, like nail kegs, in which to spawn. Females spawn only once a year but males, at least in the southern United States, "may spawn several times," (Miller 1966).

Spawning behaviour is said to be much like that of the brown bullhead and was described in detail by Clemens and Sneed (1957). There is one claim that males secrete mucus which gives a smooth waxy surface to the bottom of the nest. Eggs are 450–500 per ounce and yellow when laid but become browner as hatching nears. Before they are laid, they are 3.5–4.0 mm in diameter. Females 1–4 pounds bear approximately 4000 eggs and a female 26 inches (660 mm) long, was estimated to have 34,500 eggs. Males protect the nest after egg laying, aerate and clean the eggs by fanning with the paired fins, and press and pack the eggs with body and fins. Eggs hatch in 5–10 days at temperatures from 60° to 82° F (15.6°–27.8° C). Newly hatched fish have large yolks and remain on the bottom for 2–5 days and then swim to the surface and begin to feed. The development of eggs, embryo, and young was described in detail by Fish (1932), Saksena et al. (1961), and Mansueti and Hardy (1967). Like other catfishes, the male probably broods the young.

Growth is rapid in early years and young in October in Ohio were 2–4 inches (51–102 mm) long, and at 1 year of age were 3.5–7.5 inches (89–190 mm) long. At capture, age–length relations (interpreted from pectoral spine sections and vertebrae) and weight for the St. Lawrence River, western Lake Erie, and the Mississippi River were as follows:

	St. Lawrence R., Que.			Western L. Erie			Upper Mississippi R., Iowa	
Age	Avg FL		Wt	Avg FL		Wt	Avg TL	
	(inches)	*(mm)*	*(lb)*	*(inches)*	*(mm)*	*(lb)*	*(inches)*	*(mm)*
1+	3.9	100	–	2.5	63	0.005	–	–
2+	6.7	170	–	6.5	166	0.10	9.8	249
3+	8.0	205	.18	8.9	226	0.25	11.7	297
4+	9.4	240	–	10.6	268	0.41	13.7	348
5+	10.2	260	.47	11.7	298	0.55	15.7	399
6+	11.2	285	–	13.0	328	0.76	18.1	460
7+	12.0	305	.75	14.3	362	0.98	21.0	533
8+	12.6	320	–	–	–	–	22.3	566
9+	13.3	338	–	–	–	–	24.9	632
10+	13.8	350	1.15	–	–	–	28.0(1 only)	711
11+	14.5	370	–	–	–	–	26.2(2 only)	665
12+	15.0	382	–	–	–	–	28.3(2 only)	719
15+	16.3	415	1.96	–	–	–	–	–
20+	18.3	465	2.76	–	–	–	–	–
24+	19.5	495	–	–	–	–	–	–

There is tremendous variability in growth depending on habitat, and a very significant increase in growth rate southward. Length at age 10 in the St. Lawrence River is about 14 inches (356 mm), in the Ottawa River about 14.3 inches (363 mm), in Lake Erie about 17 inches (432 mm), and in the Mississippi River in Iowa about 28 inches (711 mm). The expression for the length–weight relation also emphasizes this difference. Those expressions for the St. Lawrence River, Lake Erie, and the Mississippi River at Lansing, Iowa, were as follows: $\log W = -4.012 + 3.039 \log FL$; $\log W = -4.910 + 2.956 \log TL$, and $\log W = -6.759 + 3.66 \log TL$, where W is weight in grams, and FL and TL are fork and total lengths in mm.

Size at sexual maturity in Canada is not known, but in the south they usually mature at 10.5–16.0 inches (267–406 mm), and 5–8 years of age. In some natural areas, they mature as early as 2 years and in ponds in Texas at 18 months.

Channel catfish often grow to weights of over 30 pounds in Canada. Bensley (1915) reported a specimen from Georgian Bay which weighed 37 pounds. However, in waters other than the Great Lakes, weights of 2–4 pounds are most common with occasional fish up to 10 pounds. Magnin and Beaulieu (1966) mentioned a specimen from the St. Lawrence River which was 29 inches (737 mm) in fork length, weighed over 16 pounds, and was said to be near 40 years of age. Trautman (1957) said that Ohio commercial fishermen gave maximum weight as 32–38 pounds but that average size was 11–30 inches (279–762 mm) and 12 ounces to 15 pounds in weight. He cited the largest specimens as 33–46 inches (839–1169 mm) in length and 25–30 pounds in weight. The *Field and Stream* anglers' record is a fish which weighed 58 pounds, was 47½ inches (1202 mm) in length, 29⅛ inches (716 mm) in girth, and was caught in the Santee–Cooper Reservoir, S.C., in July, 1964. Other than the estimated 40 years for the single St. Lawrence River specimen, maximum age in Canada would appear to be 24 years. Faster growing populations to the south have not been estimated to exceed 14 years of age, and some only 7 years.

The habitat of the channel catfish in Canada is lakes and moderate to large rivers. They usually inhabit cool, clear, deeper water with sand, gravel, or rubble bottoms and not the shallower, more turbid, vegetated areas frequented by the bullheads. During the day they are most often found in deeper holes in the protection of rocks or logs. Young and smaller adults often move short distances at night, out of lakes into the fast water of tributary rivers, in order to feed. Although largely sedentary animals, local movements in lakes have been recorded and in some areas there are marked downstream movements in fall. Marked fish liberated at lake centre returned quickly to site of marking. Greatest periods of movement appear to be just before sunrise and sunset. Fish tagged in the St. Lawrence River by Magnin and Beaulieu were later recaptured upstream, downstream, and some distance up tributary rivers. Distance travelled varied from 0 miles (30%) to 75–99 miles (0.34%) with approximately 50% of the individuals moving 10–39 miles. Those authors gave records of four catfish tagged in fresh water and later recaptured in an area downstream (Montmagny) where the deep water was 5‰ saline, and a single individual in an area (Rivière Ouelle) where the salinity at the surface was 19‰ and at the bottom 21‰. They quoted Vladykov as saying that in the St. Lawrence many channel catfish spend the winter in fresh water in the area of Lac St. Pierre, in the spring when the ice melts they descend the river toward salt water, and after mid-September they begin to move upstream again.

Lethal oxygen levels were calculated by Moss and Scott (1961) at 0.95, 1.03, and 1.08 ppm at temperatures of 77°, 86°, and 95° F (25°, 30°, and 35° C). Maximum survival temperatures of 86.5°, 91.0°, and 92.3° F (30.3°, 32.8°, 33.5° C), for acclimation temperatures of 59°, 68°, and 77° F (15°, 20°, 25° C) were determined (Strawn 1958, *in* Carlander 1969) but Moss and Scott had them survive at 95° F (35° C).

This species feeds on a wide variety of plant and animal material. They may feed both at night and during the day. Bottom feeding is more characteristic but food is obviously taken at the surface, especially by younger fish. This species, like the other catfishes, doubtless depends on its barbels and sense of taste at night, but there is a suggestion it feeds more by sight than other catfishes in its clearer habitat. There are no Canadian food studies. The young feed primarily on aquatic insects. Older fish feed on mayflies, caddisflies, chironomids, molluscs, crayfish, crabs, green algae, larger water plants, tree seeds, such fishes as are present in the habitat and, rarely, birds. In Canada various minnows and yellow perch dominate. *See* Bailey and Harrison (1948) for the food of this species in Iowa.

The young may fall prey to a variety of fishes but the adults, by virtue of their size, are probably comparatively free from predation. Except in areas where algae and other plants form a large part of its diet, the channel catfish probably competes for food with all other bottom feeders and some predatory species of fishes in its habitat.

A hybrid between this species and the flathead catfish *Pylodictis olivaris* (Rafinesque) has been reported. Sneed (1964) gave results of an attempt to produce artificial hybrids with blue, white, and flathead catfishes.

The parasites listed for this species (as *I. punctatus* and *I. anguilla*), over the whole of its range, by Hoffman (1967) were as follows: Protozoa (14), Trematoda (22), Cestoda (6), Nematoda (8), Acanthocephala (2), leeches (3), Crustacea (6). Notes on parasites of this species in the Great Lakes were given by Bangham and Hunter (1939) and Bangham (1955).

Relation to man This species is an excellent food fish, a commercial fish of some importance in the Great Lakes and St. Lawrence River, and a formidable sport fish. The flesh is white, flaky but solid and very flavourful. Some people find it too rich or strong, and stripping the "red muscle" from the centre of the sides usually avoids this. The commercial statistics isolate this species as catfish, contrasted with bullheads for the composite catch of the smaller species. The catch in Ontario between the years 1964 and 1968 varied from a high of 990,000 pounds in 1967 to a low of 620,000 pounds in 1966, and for Canada as a whole from a high of 1,243,000 pounds in 1964 to a low of 693,000 pounds in 1966. Market value in Canada ranged from a high of $232,000 in 1967 to a low of $158,000 in 1966. In 1968, in Ontario, the catch was 651,000 pounds, the value to the fisherman $142,000 or 21¢/pound, and the marketed value was $160,000. Lakes St. Clair and Erie yield the highest commercial catches. It is a very important commercial species in the Mississippi River areas of the United States and on fish farms there. Commercial production apparently regularly falls behind demand.

The channel catfish, although a challenging sport fish because of its potential size, was, in the past, actively sought after by only a limited number of anglers in Canada. This was possibly because best catches were possible only after dark and usually in areas where angling is difficult and hard on tackle. Many were caught, however, while fishing for other species. A growing number of anglers now search them out in various rivers in order to try to catch even heavier individuals. Channel catfish are usually caught by still fishing, in rapid river water near falls and dams, at dusk to early night, with large minnows, pieces of fish or meat, or large balls of worms.

This species is an excellent pond-culture fish and is extensively so used in the United States. *See* Regier (1963b) for its use in farm ponds in New York State, where crops up to 300 pounds per acre have been obtained, and Miller (1966) for summaries of propagation management, standing crop, and angling success rates in various localities in the United States. Channel catfish have been successfully used for angling in artificial ponds in a public fishing area in Ontario.

The spines of this and other species of catfishes have always been part of Indian artifacts. The bases were rounded, the barbs removed, and the spines used as awls for leather work or, if the hole in the base was intact, as needles. One such specimen from the shores of Lake Huron in Ontario was carbon dated at 1000 years B.C.

Nomenclature

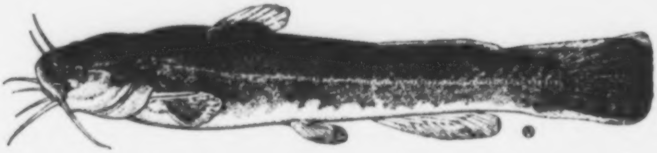
Silurus punctatus — Rafinesque 1818c: 355 (type locality Ohio River)
? *Pimelodus nigricans* — LeSueur 1819: 153
Silurus (*Pimelodus*) *borealis* (Richardson) — Richardson 1836: 135
Pimelodus nigricans — Forelle 1857: 281
Synechoglanis beadlei — Gill 1859: 40 (type locality St. Catharines, Ont.)
Amiurus borealis — Günther 1864: 100
Amiurus caudifurcatus — Günther 1864: 102
Ictalurus lacustris (Walbaum) — Jordan and Gilbert 1883a: 108
Ictalurus punctatus Rafinesque — Eigenmann 1895: 107
Ictalurus punctatus (Rafinesque) — Jordan and Evermann 1896–1900: 134
Ameiurus lacustris (Walbaum) — Jordan and Evermann 1896–1900: 137
Ictalarus nigricans (Lacépède) — Montpetit 1897: 251
Ictalurus punctatus (Rafinesque) — Jordan, Evermann, and Clark 1930: 152
Haustor lacustris (Walbaum) — Jordan, Evermann, and Clark 1930: 152
Ictalurus punctatus Rafinesque — Hubbs 1926: 49
Villarius lacustris Walbaum — Hubbs 1926: 50
Ictalurus lacustris — Radforth 1944: 64
Ictalurus lacustris lacustris (Walbaum) — Hubbs and Lagler 1941: 63
Ictalurus punctatus (Rafinesque) — Speirs 1952: 101
Ictalurus punctatus punctatus (Rafinesque) — Hubbs and Lagler 1958: 90

Etymology *Ictalurus* — fish cat; *punctatus* — spotted (characteristic only of individuals under 12 inches or 305 mm).

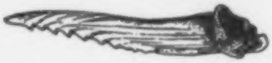
Common names Channel catfish, channel cat, spotted catfish, Great Lake catfish, Great Lakes catfish, lake catfish, northern catfish. French common name: *barbue de rivière*.

STONECAT

Noturus flavus Rafinesque



Description This small catfish, usually no more than 6–8 inches (152–203 mm) in total length, is the largest of the three catfishes in Canada with an adnate or attached adipose fin. For detailed description *see* Taylor (1969). Body round at dorsal and pelvic fins, somewhat laterally compressed behind this, little change in dorsal or ventral bodyline, not markedly potbellied, greatest depth, at dorsal origin, 12.8–21.9% of total length; caudal peduncle short but deep, depth 9.2–11.6% of total length. Head very wide at rear but not long, length 21.0–24.5% of total length, interorbital width 36.7–46.1% of head length, pronounced longitudinal groove between eyes in breeding individuals, head naked; eye small, round, protruding, almost on top of head, diameter 9.2–17.6% of head length, possibly smaller in areas of heavy silt; snout fleshy, somewhat pointed, length 35.2–41.5% of head length, broad and flat on top, overhangs mouth, posterior nostril of each pair opening through base of snout barbel, barbel reaches to posterior edge of eye; mouth horizontal, subterminal, overhung by fleshy upper lip, upper jaw short, gape just reaching level of posterior nostril, lips fleshy, 1 pair flattened maxillary barbels, longest of 4 pairs of barbels but do not reach to edge of operculum; fine cardiform teeth in several irregular rows on premaxillary, dentary, and in patches on last pharyngobranchial bones, patch on premaxillary broad, rectangular, with backward lateral extensions, and somewhat constricted at centre; undersurface of head broad and flat, 2 pairs of barbels on chin, inner pair shorter. Gill rakers moderately long, pointed, widely spaced, 5–10 in number, usually 4–6 on lower arch and 1 or 2 on upper arch, but as high as 8 on lower arch in Alberta. Branchiostegal rays usually 10 on each side (9–11 over whole range) but often 9 or 11 on one side. Fins: dorsal 1, origin ahead of midpoint of body, tip of snout to dorsal origin 28.3–32.3% of total length, 6, or rarely 7, soft rays and 1 obvious, weak spine (modified soft ray), spine almost straight, about ⅓ height of fin, pointed, no barbs on posterior edge; height of fin about equal to base length which is 9.7–12.2% of total length, edge rounded; adipose low, long, length 13.7–19.1% of total length, adnate (attached to back) for whole length, connected to anterior edge of caudal fin, and connected by low ridge to dorsal insertion; caudal broad, margin fleshy, tip rounded to truncate; anal with long base, 15.6–18.4% of total length, low, greatest height about ¼ base length, fleshy edge rounded, rays 15(9), 16(12), 17(1), usually 16(not counting 2 anterior rudiments); pelvics abdominal, origin behind dorsal insertion, low, very round, not reaching anal base, rays 8–10, usually 8; pectorals rather high, broad, edges square to slightly rounded, anterior spine stout, about ¾ length of fin, posterior edge smooth to roughened, anterior surface weakly barbed near tip, 1 spine and 8(3)–11(1) rays, usually 9(5) or 10(5), poison gland opening by pore above base of



fin (*see* Reed, 1907, 1924a, b). Skin naked; lateral line incomplete and short. Peritoneum colourless, intestine coiled and well differentiated, no pyloric caeca. Swim bladder of 2 chambers. Vertebrae usually 38 or 39 (37–41 over whole range) not counting anterior, fused vertebrae (Weberian ossicles).

No nuptial tubercles.

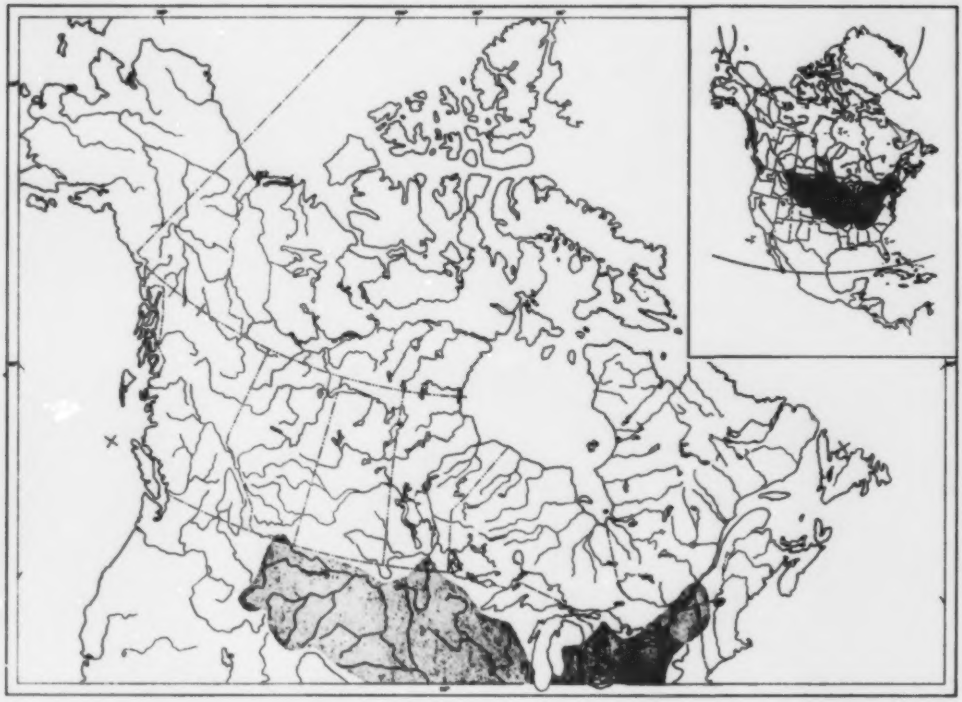
Colour Dorsal surface of body and head yellow, slate-grey, olive, to steely blue; areas around top of head, dorsal fin base, and between dorsal and adipose fins dark grey, sides lighter yellow-grey, lower surface of head and ventral surface of body white to grey. Pelvic fins, lower edge of caudal peduncle, edges and sometimes end of caudal fin, and edge of adipose fin white; a grey blotch extends into adipose fin; irregular dark grey blotch covers most of middle of caudal fin; anal fin lightly pigmented, dorsal fin with light margin, a distal dark grey band and intermediate light grey area; pectoral fins dark grey, white margins, upper edge of pectoral spine dark grey, front edge white; upper barbels grey, chin barbels white; a light yellow elliptical or oval spot at posterior end of dorsal fin (Taylor 1969). A colour illustration appeared in Greeley (1929).

Systematic notes Rafinesque's original description may be a composite of *N. flavus* and *N. gyrinus* (Taylor 1969). Characteristics of this species seem comparatively stable over the disjunct Canadian range, and in fact, over the whole range, according to Taylor, but his Canadian material was limited. Stewart and Lindsey (1970) reported two dorsal spines in Manitoba material. In small, cleared and stained ictalurid specimens, a primary unit shows, which later fuses to the main spine. Those authors also listed 44 or 45 vertebrae and contrasted this with the counts for Kansas of 41–44 given by Cross (1967). Taylor gave counts (less anterior fused vertebrae) for Nebraska to Montana as 37–40 and gave no counts over 41. It is probable that the high Manitoba count includes the five fused anterior vertebrae; if not, this most northerly population is unique. Gill rakers in Ontario were 4–6 + 1–2 but a single specimen from Alberta had 8+2. Eye diameter in Alberta was smaller but Taylor said that varying degrees of reduction in size or function of eyes occurred in populations in silted water. Head length seemed greater in the Alberta population compared with Ontario specimens.

Distribution This species is restricted to the fresh waters of North America. It occurs from the St. Lawrence River and tributaries in Quebec, south in the Hudson, Allegheny, and Mohawk systems in New York (a canal immigrant?), west of the mountains, to western North Carolina and northern Alabama (Tennessee River), north through central Tennessee, west through northern Missouri, Kansas, and northeastern Colorado, northwest from Wyoming to Alberta, east through North Dakota, north into Manitoba, southeast across the tip of Lake Superior to central Michigan and into southern Ontario and Quebec.

In Canada the stonecat occurs in the St. Lawrence River and its tributaries in Quebec, from Rivière Etchemin (at Lévis) upstream; in the lower Ottawa River, in tributaries of lakes Ontario, Erie, and Huron (excluding Georgian Bay) to the level of the tip of the Bruce Peninsula. Absent west to the Red River, north in that river only to Winnipeg, Man., absent from Saskatchewan, present in the Milk River (Missouri River drainage) of southern Alberta.

The distribution of this species, in Canada, west of Ontario has long been argued as the result of various interpretations of unverified published records for: Medicine Hat, Alta., (Eigenmann 1895); Manitoba (Bissett 1927); Hudson Bay drainage (Bajkov 1928); and for the Red and Assiniboine rivers in Manitoba, and the South Saskatchewan River in eastern Alberta, (Hubbs and Lagler 1947; Rostlund 1952). Because of this doubt, Taylor (1969) tentatively placed the Manitoba records of *N. flavus* of Bissett, Bajkov, Jackson (1934), Hinks (1943), and Dymond (1947) in the synonymy of *N. gyrinus* which was known to occur there. The presence of the stonecat in Alberta was veri-



fied by Nursall and Lewin (1964) and by Willock (1968). Stewart and Lindsey (1970) confirmed its presence in Manitoba when they reported on nine specimens taken in the Red River near Winnipeg in the summer of 1969. Underhill (1957) and Taylor (1969) considered it absent from the Red River in Minnesota. We must assume it is present there, or it was at one time, or that the Manitoba population resulted from an introduction.

Biology Almost nothing is known of the biology of this species in Canada or elsewhere. Most of the following was derived from Carlander (1969), Taylor (1969), and Greeley (1929). It spawns in the summer over a long period possibly ending as late as August. Peak period of spawning commences in June or July when water reaches 82° F (27.8° C). It may spawn in streams or shallow, rocky areas of lakes. The mass of sticky eggs is deposited beneath stones. The eggs are yellow, opaque, 3.5–4.0 mm in diameter, and coated with a jelly. Average egg number per female is 973 with a range of 767–1205 (Carlander 1969). Approximately 500 are laid in an adhesive mass and guarded by the male. Fish (1932) gave details of eggs and early development of young.

The young in Ohio in October were 1.2–3.2 inches (30–81 mm) (Trautman 1957). Average standard length at capture for various ages in Lake Erie and in Ohio streams was given by Gilbert (1953) as follows:

Age	Avg SL	
	(inches)	*(mm)*
1	2.1	53
2	3.0	77
3	3.5	89
4	3.8	98
5	4.2	107
6	4.9–8.1	126–207
7	8.2	209
8	–	–
9	9.1	233

Growth is slow but more rapid in lakes where food is more abundant. Average size is 6–8 inches (152–203 mm). Trautman (1957) gave maximum size in Ohio as 12.3 inches (312 mm) and 1 pound 1 ounce. They have been recorded in Alberta to 9 inches (229 mm) total length and to 12 inches (305 mm) in Ontario (Lake Erie). Maximum age is probably 8–10 years.

The stonecat prefers riffles or rapids of moderate or large streams with bottoms of large, loose rocks. It is present in lakes near sand and gravel bars where there is wave action. It may move into quiet water to feed. In the United States it is usually absent from streams of low gradient (but present in Red River, Man.) and disappears from streams which are impounded. Johnson (1965) found this species in streams near Toronto, Ont., in numbers per acre ranging from 23 to 164, representing standing crops of 0.3–2.3 pounds/acre. They were associated with suckers, a variety of minnows, rock bass, and two darters. Elsewhere they are found regularly with smallmouth bass. Hallam (1959) found them associated with trout in Ontario but only in the warmer trout habitats. They may occur from shore to 20 fathoms in the Great Lakes.

The food of the stonecat is primarily immature aquatic insects, largely mayflies, and, secondarily, molluscs, minnows, crayfish, and plant material. Much of its food is searched for along the bottom, probably by means of its sensitive barbels and probably at night.

This species is doubtless free of much predation but has been known to have been eaten by smallmouth bass and a watersnake. It is a competitor for bottom organisms with other bottom feeders, particularly smallmouth bass, which has similar habitat requirements.

The parasites of the stonecat were listed by Hoffman (1967) as: Trematoda (4), Cestoda (2), Nematoda (1), and Acanthocephala (4).

Relation to man This species is small, secretive, nocturnal, and not often seen by the layman. When seen, it is often mistaken for the young of the brown bullhead. It is of little commercial or sport-fish value, but Greeley (1929) said that the flesh was excellent. One interesting relation to man is that it is one of three freshwater fishes in Canada which can inflict a painful, but not dangerous, wound from the pectoral spine and the poison gland associated with it (*see* Reed 1907, 1924a, b).

Nomenclature

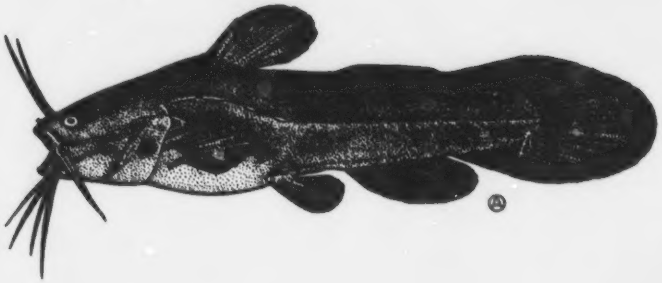
Noturus flavus — Rafinesque 1818d: 41 (type locality Falls of the Ohio, neotype (Taylor 1969) USNM 202494)
Noturus platycephalus — Günther 1864: 104
Noturus flavus Rafinesque — Bailey et al. 1960: 18

Etymology *Noturus* — tail over the back in allusion to the connection between adipose and caudal fins; *flavus* — yellow.

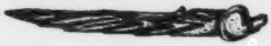
Common names Stonecat, stone catfish, stonecat madtom, catfish, white cat, doogler, beetle-eye. French common name: *barbotte des rapides*.

TADPOLE MADTOM

Noturus gyrinus (Mitchill)



Description This species is the smallest of the catfishes in Canada and the smallest of the 3 species with an adnate adipose fin. It seldom exceeds 3.5 inches (90 mm) in length. Meristics given below involve specimens from Quebec to Saskatchewan but percentages are based on specimens from Ontario and Manitoba. Body very heavy and round forward, pot-bellied; greatest depth, at dorsal spine, 16.8–22.9% of total length; strongly laterally compressed behind origin of anal fin; steep angle from tip of snout to origin of dorsal fin; very tadpolelike in shape and colour; "caudal peduncle area" long, deep, depth 10.2–12.9% of total length. Head massive, deep but not long, length 22.5–26.5% of total length, wide, interorbital width 38.4–49.4% of head length, head naked, rounded to flat on top; eye very small, diameter 9.3–16.2% of head length, high on head, slightly protruding; snout moderate, length 35.1–42.0% of head length, broad, rounded to flat on top, does not overhang mouth, 1 pair long, broad, flattened barbels on snout; mouth terminal, horizontal, jaws equal in length, mouth short and wide, gape extending to posterior nostril, lips fleshy but not prominent, 1 pair long, flattened, maxillary barbels reach almost to head length; fine, cardiform teeth in several irregular rows on lower jaw and premaxillary, premaxillary patch short, wide, ends rounded and without rear extensions; undersurface of head broad, flat, with 2 pairs of heavy barbels often of little difference in length. Gill rakers usually 8, 6 or 7 on lower limb, 1 on upper limb. Branchiostegal rays usually 9, but rarely 8 on one side, (8–10 over whole range). Fins: dorsal 1, well ahead of midpoint of body, tip of snout to dorsal origin 27.8–31.6% of total length, soft rayed but first obvious ray modified to a stout spine, spine about ⅔ height of fin, straight, sharply pointed, no barbs or serrae, height of fin greater than base length which is 9.5–12.6% of total length, edge rounded, 1 spine and 5–7, usually 6 rays, 5(1), 6(25), 7(2); adipose thin to fleshy, long, 14.5–17.0% of total length, low, adnate, no conspicuous ridge to insertion of dorsal fin, connected to long extension of caudal but slight notch between; caudal long, with long dorsal and ventral extensions of procurrent rays, broad, tip rounded; anal base long, 10.8–19.4% of total length, fin height at least ½ base length, longest rays toward rear, edge rounded, 14–16 rays, usually 15, 14(7), 15(17), 16(3), (excluding anterior rudiment) but 2 very small specimens from Niagara River tributary appear to have 17 rays; pelvics abdominal, origin behind insertion of dorsal fin, low, very broad, and round, tips overlap origin of anal fin, usually 8, rarely 9, rays; pectorals appear high as result of potbelly, broad, edge straight, tip pointed, 1 spine and 6–9, usually 6, rays,



6(16), 7(8), 8(3), 9(1), spine heavy, sharply pointed, almost straight, at least ⅗ length of fin, no barbs or serrae but sculptured and posterior surface deeply grooved, with associated poison gland (*see* Reed 1900, 1907, 1924a, b). Skin truly naked of scales; lateral line incomplete, short curved upward above pectoral fin; muscle blocks obviously outlined on compressed part of body. Peritoneum not pigmented, intestine well differentiated, no pyloric caeca. Vertebrae 33 or 34 (not counting fused anterior vertebrae), 32–37 over whole range.

No nuptial tubercles, but certain muscles on the head of males swell at spawning time.

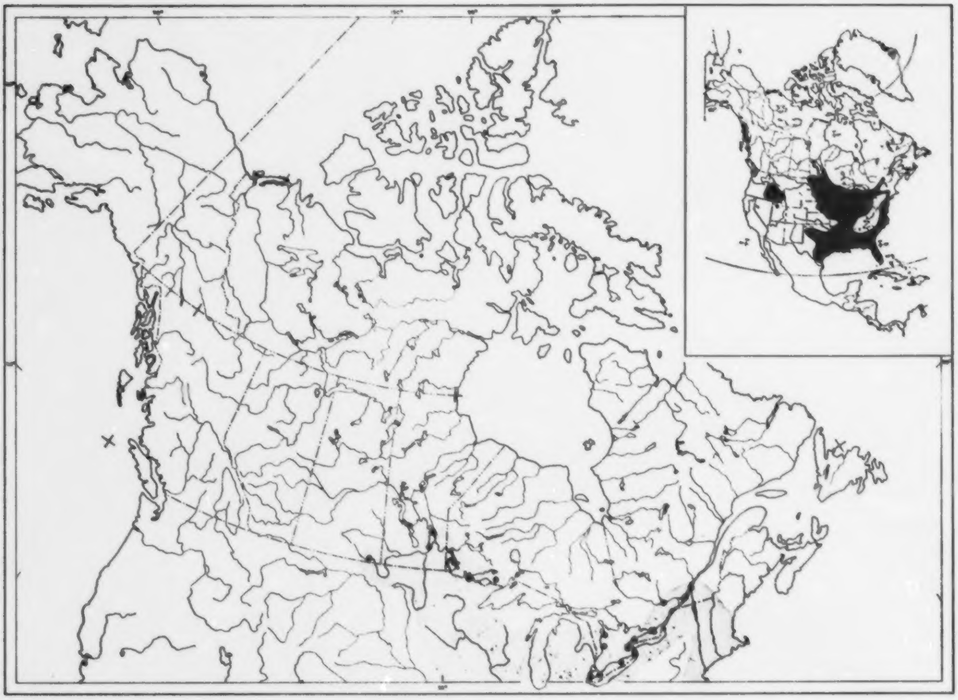
Colour Over the whole range colour varies from dull golden yellow to olive-grey, but preservation usually turns the animals grey, brown, or nearly black. Fins, barbels, and upper body are nearly uniform in pigmentation but barbels and fins may be darker or lighter than adjacent body. The tips only of the lower barbels are, at times, white. A dark grey streak is present along the position of the vertebral column and this branches into the dark lines outlining the muscle segments. The ventral surface of the body to the pelvic fins is always lighter or unpigmented in the young and lightly or irregularly pigmented in adults (mostly from Taylor 1969).

Systematic notes Records of this species are rather confusing as it was once known as *Noturus gyrinus*, then *Schilbeodes gyrinus*, then *Schilbeodes mollis* and now, once again, *Noturus gyrinus*. Taylor (1954, 1955, 1969) gave reasons for combining the genera *Schilbeodes* and *Noturus* and reversed the decision of Hubbs and Raney (1944) concerning the trivial names *gyrinus* and *mollis*. Because of the doubt, prior to the record of Stewart and Lindsey (1970), concerning the presence of *N. flavus* in Manitoba, Taylor tentatively placed in the synonymy of *N. gyrinus* the Manitoba records for *N. flavus* of Bissett (1927), Bajkov (1928), Jackson (1934), Hinks (1943), and Dymond (1947).

There is little variation in the Canadian specimens of this species examined, and the meristics appear to fit into the "strong north-south gradients" mentioned by Taylor. All counts fit within his total values. Two (of three) very small specimens from a tributary of the Niagara River appear to have 17 anal rays. This is within the total range (12–18) given by Taylor but outside his range for the Great Lakes (13–16), and is one more than the range in an adjacent Niagara River tributary.

Distribution The native distribution of this species is restricted to eastern and central North America. It occurs in fresh water, and the slightly brackish water of tidal areas, from the Hudson and Mohawk rivers, Finger Lakes, and Lake Ontario drainages of New York; south, east of the mountains, but below the fall line, to southern Florida; west through the southern half of Georgia and Alabama, through all of Mississippi and Louisiana, to the Nuecas River, Texas; north through eastern Texas, southern Oklahoma, eastern Arkansas; north in the Mississippi River and then spreading west in central Missouri; northwest through the eastern halves of the states from Kansas to North Dakota and into Saskatchewan; east through southern Manitoba, western Ontario, southern Wisconsin and Minnesota to extreme southern Ontario and Quebec. It has been introduced in New Hampshire, Connecticut, Idaho, Oregon, and possibly elsewhere where bullheads have been introduced.

In Canada, the tadpole madtom occurs in the St. Lawrence River and tributaries in Quebec at least as far downstream as the Richelieu River; at least the Nation and Castor rivers of the Ottawa system; lakes Ontario, Erie, St. Clair, Huron, and their tributaries; the Quetico–Rainy River portions of the Hudson Bay drainage in western Ontario; the Red River in Manitoba, downstream at least to Black Bear Island in Lake Winnipeg; and the Souris River in Saskatchewan. There seems no basis for the inclusion of Alberta by Scott (1967).



Biology There is no published study of the biology of this species in Canada, and very little from elsewhere. The following information was derived mainly from Bailey (1938), Hooper (1949), Trautman (1957), and Carlander (1969). Tadpole madtom spawn in summer, probably in late June and July in Canada, usually in rivers but to a lesser extent in lakes in shallow water. They probably build their nests in dark cavities, as many of the known egg clusters (and many specimens) have been removed from open tin cans seined off the bottoms of streams or lakes. Egg number varies and has been cited as an average of 50, or as high as 93. Since one nest in New Hampshire contained 117 eggs, either the number is higher than 93, or more than one female contributes to a brood. Eggs are light yellow, about 3.5 mm in diameter, including a gelatinous envelope. They adhere to each other and to the substrate, and the whole egg mass is surrounded by another gelatinous envelope. Mansueti and Hardy (1967) gave details of eggs and early development of young. In Iowa, the young are 0.9–1.3 inches (23–35 mm) long in July and 0.7–2.2 inches (18–56 mm) in September. Age–standard length relation (by vertebrae) for a lake in Minnesota was given as follows:

Age	SL			
	Average		Range	
	(*inches*)	(*mm*)	(*inches*)	(*mm*)
0	1	26	0.6–1.3	15–35
1	2.4	62	1.9–3.3	48–85
2	3.5	89	3.0–4.1	78–104

Maximum age would appear to be 2 or 3 years in Canada. Maximum size known in Canada is 4.3 inches (110 mm) total length, 3.5 inches (104 mm) standard length in Minnesota, and 4.4 inches (112 mm) in Ohio. The largest Canadian specimen is from the Hudson Bay drainage of Saskatchewan (Souris River).

The tadpole madtom is usually considered to inhabit quiet, slow moving, clear waters, shallows of lakes and their outlets, sloughs, ponds, backwaters, and stream mouths, with soft, muddy bottoms and extensive vegetation. It has been taken as deep as 81 feet (25 m). Habitat destruction and silting is restricting the distribution of this species and may be reducing its numbers in the United States. The tributaries of Lake Erie in Ontario in which it occurs are often turbid. It is active only at night, retiring in the daytime to the protection of cavities, cutbanks, debris, or vegetation.

Food of this species has been reported to be Cladocera, ostracods, *Hyalella*, chironomids, and other immature aquatic insects including dragonflies. It forages for these on the bottom, at night.

Although armed with "poisonous" spines, this madtom is eaten by other fishes and is used as bait for other fishes. There is a record of a tadpole madtom eaten by a gartersnake. They compete with other bottom feeders for food.

Hoffman (1967) listed the parasites as Protozoa (2), Trematoda (6), Cestoda (2), Nematoda (2), Acanthocephala (2), and Crustacea (1).

Hybrids between the tadpole madtom and the brindled madtom were described by Trautman (1948) and Taylor (1969).

Relation to man In Canada this fish is too small, too rare and too poorly known to be of any relation to man other than in its ecological role. Where abundant in the United States, they are food of more favoured fishes and are said to be excellent as bait for other fishes. Although little known in Canada, they are quite abundant in some areas in the United States. Hooper (1949) reported that they contributed more weight (88 of 251 pounds) than any other of the five species taken by poisoning a 12.5-acre lake in Minnesota. The lake contained over 4200 madtoms. It is probably often mistaken for the young of the commoner brown bullhead. Its secretive nature leads it to occupy empty tin cans on the bottom of streams and lakes and these should be examined in any search for this animal. It is of interest in that it is one of three freshwater fishes in Canada that can inflict a painful, but not dangerous, wound with its sharp pectoral spine and associated poison gland (*see* Reed 1900, 1907, 1924a, b).

This small fish, as a result of its size and habitat requirement, makes an interesting aquarium resident and, as such, was taken to Germany. It apparently never succeeded there in natural habitats.

Nomenclature

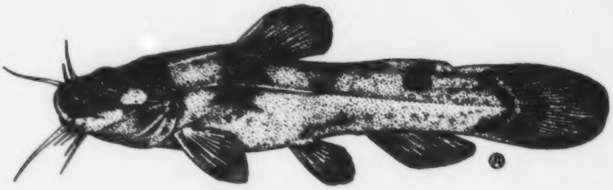
Silurus gyrinus — Mitchill 1817: 289 (type locality Wallkill River, N.Y.)
Noturus sialis — Jordan 1877a: 102
Noturus gyrinus — Wright 1892: 443
Schilbeodes gyrinus — Nash 1908: 24
Schilbeodes gyrinus sialis (Jordan) — Greeley 1936: 36
Schilbeodes mollis (Hermann) — Dymond 1947: 23
Noturus gyrinus (Mitchill) — Taylor 1954: 44

Etymology *Noturus* — tail over back in allusion to the adipose fin joined to the caudal fin; *gyrinus* — tadpole.

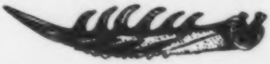
Common names Tadpole madtom, mad tom, tadpole stonecat, tadpole cat. French common name: *chat-fou brun.*

BRINDLED MADTOM

Noturus miurus Jordan



Description This species, although not the smallest of the three catfishes in Canada with adnate fins, rarely grows to more than 2–3 inches (51–76 mm). Body heavy forward, but less potbellied than *N. gyrinus*, angle from tip of snout to dorsal origin not steep, greatest depth at dorsal spine 8.3–20.0% of total length, strongly laterally compressed behind origin of anal fin; caudal peduncle tapers backward, short and only moderately deep, depth 8.6–10.1% of total length. Head less massive, not long nor deep, length 22.6–23.5% of total length, wide, interorbital width 23.3–31.1% of head length, flat to slightly rounded, rounded above but slight depression in older specimens, naked; eye larger, diameter 16.1–25.0% of head length, high on head, protruding; snout short, 31.0–39.2% of head length, flat to rounded on top, overhangs mouth slightly, 1 pair of long, flattened barbels on snout, much closer to eye than in *N. gyrinus*; mouth slightly subterminal, lower jaw included, mouth horizontal, wide but short, gape reaching to posterior nostril, lips not conspicuous; 1 pair of long, flattened maxillary barbels reaching almost to head length; fine, cardiform teeth in several, irregular rows on lower jaw and premaxillary, premaxillary patch sharp or slightly rounded on corners, without backward extensions; undersurface of head broad, flat, with 2 pairs of barbels of nearly equal length. Gill rakers 6–8, usually with 6 on lower limb and 1 or 2 on upper limb. Branchiostegal rays usually 9. Fins: dorsal 1, well ahead of midpoint of body, snout to dorsal origin 28.9–32.5% of total length, soft rayed but first obvious ray modified to stout spine, spine about ⅔ height of fin, almost straight, sharply pointed, no barbs or serrae, height of fin almost twice length of base, which is 10.0–12.7% of total length, edge quite round, 1 spine and 6 rays (5–7, usually 6 over whole range); adipose thin, long, 19.8–24.5% of total length, low, adnate, widely connected to long extension of caudal fin, but moderate notch between; caudal long, with long dorsal and ventral extensions anteriorly of procurrent rays, broad, tip rounded; anal base long, 13.3–16.7% of total length, fin height more than ½ base length, edge rounded, 13–15 rays, not including anterior rudiments (13–17 total rays over whole range); pelvics abdominal, origin just behind insertion of dorsal fin, low, broad and rounded, tips do not quite touch origin of anal fin, usually 8 or 9 rays (8–10 over whole range); pectorals appear lower than *N. gyrinus*, broad, edge straight, tip bluntly pointed, 1 spine and usually 8 rays but sometimes 7 (7–9 over whole range), spine heavy, sharply pointed, curved, spine almost equal to fin length, fine anterior serrae and several strong, posterior barbs easily felt, spine with associated poison gland (*see* Reed 1907, 1924a). Skin truly naked of scales; lateral line incomplete, short, shallowly curved upward above pectoral fin. Peritoneum not pigmented, intestine well



differentiated, no pyloric caeca. Vertebrae 34 or 35 (not including fused anterior vertebrae), 32–37 over whole range.

No nuptial tubercles, but, in spawning males, head broadens, flattens, and muscle masses on back, head behind eye, and on cheeks become enlarged as do lips and bases of maxillary barbels (Taylor 1969).

Colour Very conspicuously marked, hence, the common name. In life, yellow, brown, light red-orange or pink, with four dark saddle marks on the back. The sides are lightly and irregularly mottled, the undersurface to pelvic fins white to pale yellow. One saddle mark involves most of head except two large, postorbital light patches, a second is at base of dorsal fin, the third is between dorsal and adipose fin, the fourth crosses highest point of adipose fin. Dorsal fin with black submarginal blotch and dusky base; caudal fin and peduncle ringed with a black band and then white band, centre of caudal fin with one or more radiating bands of speckles; anal fin dusky at base, with row of spots in from edge; pelvic fins clear, ventrally pigmented at upper base; pectoral fins sometimes with vague, irregular spots near tip and pigment along spine heaviest on dorsal surface; all barbels light to speckled.

Systematic notes This species, originally in the genus *Noturus*, was later called *Schilbeodes*, and returned to *Noturus* by Taylor (1955, 1969).

Taylor stated that the brindled madtom showed remarkable uniformity of characters considering its wide latitudinal range. The chief geographic difference was that southern specimens were paler and more emaciated and northern ones darker and fatter.

The northern madtom, *N. stigmosus* Taylor, is known to occur in the Detroit River in the United States. It is very similar in colour, and almost identical in meristic characters (dorsal with 1 spine and 5–7 rays, anal 13–16, pelvic 9 or 10, pectoral 7 or 8, vertebrae 31–35) to *N. miurus*. This species should be watched for in collections of *N. miurus* in southwestern Ontario. The Detroit River collection has been included by various authors under the names *S. eleutherus* (Hubbs and Lagler 1941, 1947), *N. eleutherus* (Scott 1967), *S. furiosus* (Hubbs and Lagler 1958, 1964), and *N. furiosus* (Trautman 1957).

Distribution The brindled madtom occurs only in the fresh waters of east-central North America. Its range extends south from the Finger Lakes and Lake Ontario drainages of New York, west of the mountains, to the western halves of the states of Tennessee and Mississippi, west to central Louisiana, north through Arkansas to northeastern Oklahoma and southeastern Kansas, southeastern Missouri, northeast from southern Indiana to southern Michigan and southwestern Ontario and into New York.

In Canada, it occurs only in Ontario, is rarely seen, and is known only from the Sydenham River, a tributary of Lake St. Clair, Lake Erie and tributaries, and the Niagara River. It was first recorded in Canada by Hubbs and Brown (1929). It had been earlier listed for Lake Erie by Dymond (1922) but on the basis of a United States record.

Biology Nothing is known of the biology of this species in Canada. Taylor (1969) gave details of spawning in Michigan. It spawns in Michigan in July to early August, at a water temperature of 78° F (25.6° C), in rivers where current is slow, with a bottom of silt, mud and scattered emergent vegetation. Almost invariably, the brooding pair were found in tin cans in which the top was open or which had a ¾–1 inch (18–25 mm) hole in the end. The male guards the nest. The number of eggs in a cluster varied from 34–46. Eggs were large, amber, and adhered to one another. Some incomplete broods (in addition to unhatched eggs) consisted of 28–38 young. Newly hatched young are 9.5–11 mm in total length. *See* Taylor (1969) for details of early development.

Trautman (1957) reported that young-of-the-year, in October in Ohio, are 1.0–2.2 inches (25–56 mm) total length, at one year 1.4–2.5 inches (36–64 mm) total length, and as adults (2–3 years?) usually 2.2–3.8 inches (56–97 mm). They are sexually mature at

2.0–2.8 inches (51–71 mm). The largest specimen examined by Taylor was 3.4 inches (88 mm) standard length but Trautman gave maximum size as 5.2 inches (132 mm). The largest Canadian specimen in our collection is 3.3 inches (85 mm) total length and came from the Niagara River.

Specimens taken in Ontario were from clear, fast-flowing streams with gravel bottoms. Taylor said that in the United States it seems to avoid that type of habitat and that it lives in pools below riffles in lowland streams with some current, and in lakes, in areas over a soft bottom often with an abundance of leaves and twigs.

Feeding doubtless takes place at night, and food is probably immature aquatic insects, other invertebrates, and plants. *See* Baker (1916) for food of this species in Oneida Lake, N.Y.

Little is known of its predators but there is a record of it in the food of a gar. Its secretive nature and nocturnal habits may make predation difficult. It probably competes for food with other bottom feeders.

The brindled madtom seems comparatively free of parasites. Hoffman (1967) listed only four trematodes. Bangham and Hunter (1939) studied the parasites of this species in Lake Erie and cited the trematodes *Megalogonia ictaluri*, *Neascus* sp., and the cestodes *Corallobothrium fimbriatum*, and *Bothriocephalus* sp.

Schwartz (1956) described a case of death from the parasite *Clinostomum marginatum*.

Trautman (1948) described hybrids between *N. miurus* and *N. gyrinus* and Taylor (1969) added one between *N. miurus* and *N. exilis*.

Relation to man This secretive fish, rare in Canada, bears no relation to man other than in its unknown ecological role. It is interesting as one of the three Canadian freshwater species which can inflict a painful, but not dangerous, wound with its sharp pectoral spines and associated poison gland (*see* Reed 1907, 1924a).

Nomenclature

Noturus miurus — Jordan 1877b: 370 (type locality White River at Indianapolis, Ind.)
Schilbeodes miurus (Jordan) — Dymond 1922: 62
Noturus miurus Jordan — Taylor 1955: 375

Etymology *Noturus* — tail over back, in allusion to connection of caudal and adipose fins; *miurus* — curtailed, possibly referring to the short appearance of this fish.

Common names Brindled madtom, mad tom, brindled stone-cat. French common name: *chat-fou tacheté*.

Suggested Reading — Ictaluridae

APPELGET, J., and L. L. SMITH, JR. 1951. The determination of age and rate of growth from vertebrae of the channel catfish, *Ictalurus lacustris punctatus*. Trans. Amer. Fish. Soc. 80: 119–139.

CLEMENS, H. P., and K. E. SNEED. 1957. The spawning behavior of the channel catfish *Ictalurus punctatus*. U.S. Fish Wildl. Serv. Spec. Sci. Rep. Fish. 219: 11 p.

EMIG, J. W. 1966. Brown bullhead, p. 463–475. *In* Inland fisheries management. Calif. Dep. Fish Game Res. Agency.

Forney, J. L. 1955. Life history of the black bullhead, *Ameiurus melas* (Rafinesque), of Clear Lake, Iowa. Iowa State Coll. J. Sci. 30(1): 145–162.

Gilbert, C. R. MS 1953. Age and growth of the yellow stone catfish, *Noturus flavus* (Rafinesque). M.Sc. Thesis. Ohio State Univ., Columbus, Ohio. 67 p.

Hubbs, C. L., and E. C. Raney. 1944. Systematic notes on North American siluroid fishes of the genus *Schilbeodes*. Occas. Pap. Mus. Zool. Univ. Mich. 487: 36 p. + 1 pl., 1 map.

Jordan, D. S. 1877. Notes on Cottidae, Etheostomatidae, Percidae, Centrarchidae, Aphododeridae, Dorysomatidae and Cyprinidae, with revisions of the genera and descriptions of new or little known species. B. Synopsis of the Siluridae of the fresh waters of North America. *In* Contributions to North American ichthyology; based primarily on the collections of the United States National Museum. Bull. U.S. Nat. Mus. 1877–78, 10: 1–116.

Magnin, É., et G. Beaulieu. 1966. Divers aspects de la biologie et de l'écologie de la barbue *Ictalurus punctatus* (Rafinesque) du fleuve Saint-Laurent d'après les données du marquage. Trav. Pêcheries Qué. 92(12): 277–291.

Miller, E. E. 1966. Channel catfish, p. 440–463. *In* Inland fisheries management. Calif. Dep. Fish Game Res. Agency.

Priegel, G. R. 1966. Age–length and length–weight relationship of bullheads from Little Lake Butte des Mortes, 1959. Wis. Conserv. Dep. Res. Rep. Fish. 17: 6 p.

Reed, H. D. 1900. The structure of the poison glands of *Schilbeodes gyrinus*. Proc. Amer. Ass. Adv. Sci. 49: 232–233.

1907. The poison glands of *Noturus* and *Schilbeodes*. Amer. Natur. 41: 553–566.

1924a. The morphology and growth of the spines of siluroid fishes. J. Morphol. 38: 431–451 + fig. 1–14.

1924b. The morphology of the dermal glands in nematognathus fishes. Z. Morphol. Anthropol. 24: 227–264 + pl. 8–15 (incl. fig. 1–32).

Regier, H. A. 1963. Ecology and management of channel catfish in farm ponds in New York. N.Y. Fish Game J. 10: 170–185.

Taylor, W. R. 1954. Records of fishes in the John N. Lowe collection from the Upper Peninsula of Michigan. Misc. Publ. Mus. Zool. Univ. Mich. 87: 50 p.

MS 1955. A revision of the genus *Noturus* Rafinesque with a contribution to the classification of the North American catfishes. Ph.D. Thesis. Univ. Michigan, Ann Arbor, Mich. 583 p.

1969. A revision of the catfish genus *Noturus* Rafinesque with an analysis of higher groups in the Ictaluridae. U.S. Nat. Mus. Bull. 282: 315 p.

THE EELS — Order Anguilliformes (Apodes)

The body shape of the true eel is so characteristic and well known that expressions such as "eel-like" and "eel-shaped" have entered the language as adjectives to describe creatures that are not eels.

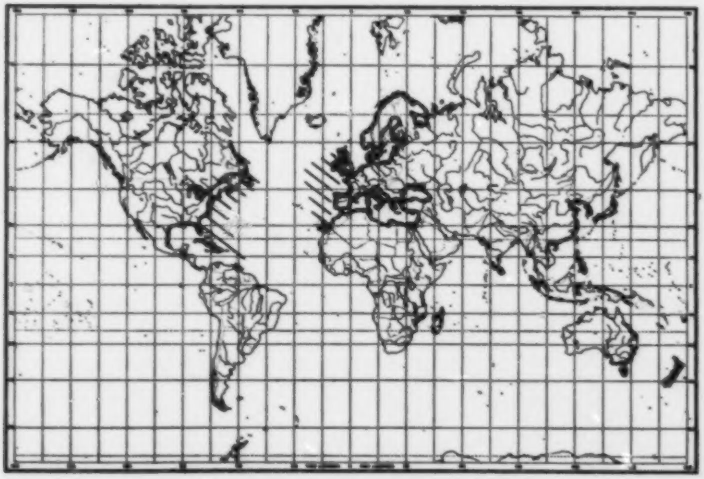
Body excessively elongate and often almost round in cross section. Skull elongated, some bony elements fused and consolidated; jaws well developed, toothed; gill opening usually small, restricted. Branchiostegal rays 6-22. Fins all soft rayed, dorsal often long, caudal, when present, ending in a point; and anal long, of many rays, but usually shorter than dorsal; pelvic fins (and pelvic girdle) absent; pectoral fins, when present, somewhat elevated to a midpoint position on sides, the bases approaching vertical orientation. Scales, when present, small, cycloid, and embedded. Physostomes. Vertebrae numerous.

The eels are primarily marine fishes widely distributed throughout the warmer seas of the world. There are about 20 families and several hundred species. Only one species enters eastern Canadian waters. Upper Cretaceous to Recent.

FRESHWATER EEL FAMILY — Anguillidae

The freshwater eels exhibit all the structural characteristics of the order, but differ in that all species leave the sea and enter fresh water early in their development and remain in fresh water throughout their lives, returning to the sea to spawn (i.e. catadromous) and presumably to die.

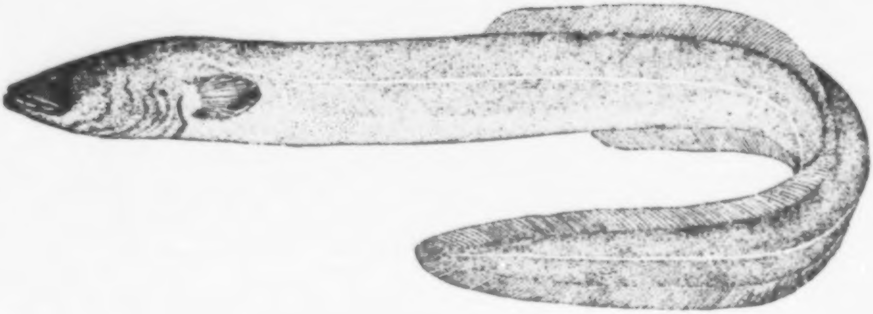
There are about 16 species, all in the single genus *Anguilla*, occurring widely throughout the world, particularly in the region of southeast Asia and the southwestern Pacific Ocean, including Australia and New Zealand. Only one species occurs in North American waters. A thorough review of the genus was prepared by Ege (1939).



World Distribution of the Freshwater Eels

AMERICAN EEL

Anguilla rostrata (Lesueur)

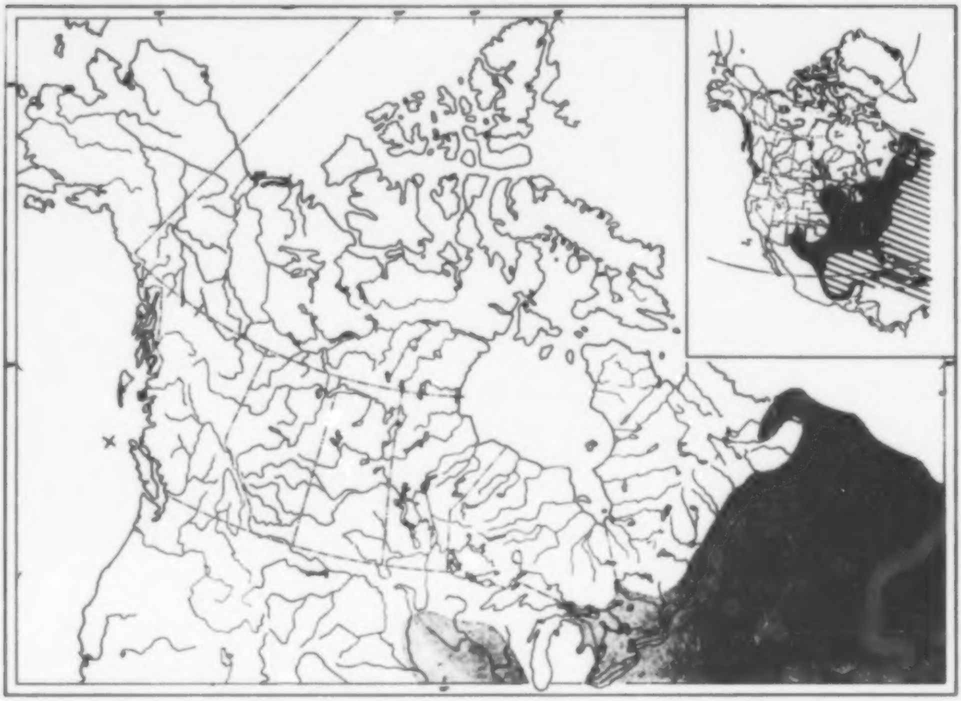


Description A full morphometric description of the American eel, in addition to the details in order and family accounts, will probably serve little purpose. The shape of the eel is so well known that words such as "eel-like" and expressions such as "slippery as an eel" are commonplace. The most characteristic features are: protruding lower jaw, gape extending to below eye or beyond; small gill opening in front of pectoral fins, which are located high on sides; dorsal fin beginning far behind head and in front of anal fin; pelvic fins absent; dorsal, anal, and caudal fins continuous; caudal bluntly rounded. Vertebrae 103–111.

Colour Colouration varies according to the developmental stage. A larval eel, called a leptocephalus, is elongate and rather lanceolate in shape, somewhat leaflike, and is transparent. Young eels, just before reaching the seashore, have the general shape of an eel, and the eyes are dark, but the body is still as transparent as glass, as in the leptocephalus stage. At this stage they are usually called "glass eels." On reaching brackish or fresh water they become greyish green and are known as "elvers." After several years in fresh water, the sexually immature adult eel is yellowish, greenish, or olive-brown in colour, sometimes with tinges of yellow, yellow-green, or orange-pink on the sides. The back is darker, the belly lighter (yellow eels). When sexually mature, in their seaward migratory state, the eels take on a metallic shine, the back is bronze or almost black, the belly is light or silvery (silver eels). For this stage, Vladykov (1955c) proposed the name "bronze eel" to correspond with the name "black eel" used by the fishermen. Eales (1968), in his study of eel fisheries in eastern Canada, says that colouration of adult eels is variable between the yellow eel and silver eel phases and states ". . . in response to changing illumination, eels can alter their skin colouration by pigment redistribution within hours."

Systematic notes Two species of eels are considered to exist in the North Atlantic region, the American eel, *Anguilla rostrata*, and the European eel, *Anguilla anguilla*. The two species are exceedingly similar but differ quantitatively in the number of vertebrae (103–111 for *A. rostrata* and 110–119 for *A. anguilla*), supposedly in the duration of the larval stage, in the larger size of North American eels, in colour, and in a few additional features.

Distribution The American eel occurs from southwest Greenland, where a few specimens were reported by Jensen (1937),



along the coast of North America, from the northernmost continental limit of range in the Hamilton Inlet–Lake Melville estuary on the coast of Labrador, south through the Strait of Belle Isle, the Gulf of St. Lawrence, and Newfoundland, occasionally off Bermuda, to the Gulf of Mexico, Panama, and the West Indies. The American eel ranges from 5° to 62°18′N lat. It is found in coastal areas and fresh waters inland to the Great Lakes, and up the Mississippi River. It is occasionally taken off the northern coast of South America. No eels exist in the south Atlantic Ocean or on the Pacific coast of North America.

In Canada the eel is abundant in the fresh and salt waters of Newfoundland, the Maritime Provinces, the Gulf of St. Lawrence and the St. Lawrence River, and all Quebec and New Brunswick rivers flowing into the St. Lawrence basin. It is also found in the Ottawa River drainage and in Lake Ontario. Relatively rare in lakes Erie, Huron, and Superior, it is considered to have gained access to these lakes through the Welland Canal rather than through the Trent Waterway, in fact there is no evidence that it ever made use of this latter route. It occurs in many inland lakes in Ontario and Quebec, tributary to the Lake Ontario–St. Lawrence River system.

Biology Few fishes have attracted the attention of North Atlantic peoples as have the eels and the salmon, dissimilar as they are in so many ways. On attaining sexual maturity, adult eels move downstream, that is, seaward, eventually to spawn in salt water. Such fishes are said to be catadromous. Salmon, on the other hand, spawn in fresh water, but move to salt water to feed and grow, returning to fresh water to spawn. They are said to be anadromous. The upstream migration of young eels in spring (mainly May and June in New Brunswick) and the downstream movement of large adults in autumn was well known, but previous to Schmidt's (1922) discoveries their life at sea was a complete mystery. Where the adults spawned, or from whence came the swarms of young eels or elvers, were unknown and subject to centuries of speculation and countless myths. Then, in 1922, after many years of intensive study, Johannes Schmidt published his classical account of the breeding places of the eel, his particular interest being the European eel. He concluded that both European and North American eels spawned in the southwest part of the North Atlantic.

But before considering the implications of Schmidt's conclusions, some biological details are in order. Unlike many other fishes, eels have a true larval stage, in which the young eel does not resemble the adult, but on hatching becomes a transparent ribbonlike creature, the eyes alone being conspicuous. At this stage, the larval eel is sometimes called a leptocephalus. By planned searching for *Anguilla* larvae at sea, using special nets to catch the fragile creatures, and plotting the lengths of larvae caught, Schmidt was able to show that the smallest larvae occurred in that region of the North Atlantic east of the Bahamas and southwest of Bermuda, an area often called the Sargasso Sea. Incidental to his search for larvae of the European eel, Schmidt caught larvae of the American eel, and concluded that its spawning ground was south and west of that of its European counterpart. It is presumed that the adults die after spawning. Larvae of European eels are thought to require up to 3 years to reach the European coast. American eel larvae arrive off our coastal waters in 1 year, and since both metamorphose, or assume the adult form, when 2.4–2.6 inches (60–65 mm) long, it is reasoned that the American larvae grow much faster than the European. For the American eel, metamorphosis apparently takes place during winter on approaching, or in, inshore waters. The larvae or leptocephalus becomes a small, transparent eel (glass eel), then pigmentation develops, and by the time it reaches streams and rivers of the coast it has become completely pigmented, is now 2.5–3.5 inches (65–90 mm) long, and is called an elver. Elvers sometimes occur in great numbers.

Despite increased oceanographic investigations, neither Schmidt nor subsequent workers have found eggs (except four eggs reported by Fish (1927) and discounted by Danish authors), concentrations of small (7 mm) larvae, or spawning adult eels at sea. Repetition or "recirculation" of Schmidt's original work has resulted in a number of authoritative-sounding statements such as: "Its spawning area is strictly confined to depths of 400 metres with the temperature of 17° C . . ."; "Each female is said to produce 15–20 million eggs. These eggs are about 1 mm in diameter"; "There, at a place where the water temperature varies between 59 and 61 degrees F. and the salinity between 36 and 37 parts per thousand, each female sheds her 10 to 20 million eggs. While the adult eels die, the larvae hatch from the eggs, turn into glass eels and, guided by an unerring instinct head for the continent from whence their parents came . . ." Many more examples could be cited, but the point is that such statements cannot be proven and were not made by Schmidt.

Recently there has been a resurgence of interest in the early life history of the eel, sparked, in large measure, by a paper by Tucker (1959). He postulated that there is only one species of *Anguilla* in the North Atlantic, that European eels never reach their spawning ground, and that European eel populations are recruited from spawning by American eels. Such revolutionary concepts beg attention. However, the current situation has been most rationally reviewed and summarized by Vladykov (1964) who explained why more data are required and suggested that the spawning grounds of *A. rostrata* may be much further south than has been considered heretofore. Obviously, much remains to be learned about the life history of the Atlantic eels.

Growth of eels in Canadian waters has not been intensively studied and accurate age–length–weight figures are not available. Smith and Saunders (1955) suggested that, although the scales are small and embedded, they can be used for age determination. In Europe, age determinations are usually made from otolith examination. The life span of the

American eel is not known for certain, but Smith and Saunders recognized nine year-classes in their study in New Brunswick lakes. In Canada large females may be 30–40 inches (762–1016 mm) long and weigh 2.5–3.5 pounds. Eales (1968) noted that females 48 inches (1220 mm) long and 16 pounds in weight have been recorded. Males seldom exceed 24 inches (610 mm) in length. North American eels are generally larger than those in Europe. The longevity of the European eel, at least in captivity, has been well attested. Vladykov (1955c) reported the case of an individual kept in captivity from 1863, when 3 years old, to 1948, a life span of 88 years! No similar authentic records are known for North American eels.

The behaviour of eels in fresh water extends the air of mystery surrounding them. They move freely into muddy, silty bottoms of lakes, lying buried in the daylight hours in summer. They apparently spend the winter buried in mud and are sought by spear fishermen who probe the bottom with specially constructed spears. Medcof (1966), reporting on a series of observations on eels, attributed to eels a chirping or sucking noise often heard on warm August evenings at Scotsville Creek, Cape Breton Island.

Eels are voracious carnivores, feeding mainly at night and consuming a wide variety of fishes and invertebrate creatures. Contrary to earlier thinking, eels seek living rather than dead creatures and are not habitual eaters of carrion, although they do attack and partly consume fishes gilled in nets.

Godfrey (1957) studied food of 300 eels in four New Brunswick streams and concluded that larger eels (i.e., over 6 inches or 152 mm long) were important predators of young salmon. But Smith and Saunders (1955), in a comprehensive study in New Brunswick waters, concluded that eels tend to avoid cool spring-fed waters, which are most important to young salmon and brook trout. Blacknose dace were the most abundant fish in the region studied by Godfrey and the fish consumed most often by eels. Although 10% of the eels examined had consumed fish, 90% contained larval insects, particularly mayfly, stonefly, and dragonfly nymphs, and chironomid larvae. Other food items included crayfish, snails, and earthworms. Laboratory studies by Perlmutter (1951) suggested that eels may be effective predators on larval lampreys.

Elsewhere eels are known to eat a variety of fishes and invertebrates, although detailed food studies have not been published. As noted by Smith and Saunders (1955) the large organic intake by eels, their large numbers, their lengthy stay in fresh water, and their subsequent seaward migration, represent a considerable loss to the nutrient cycles of lakes and streams, a loss that should be better understood and, hopefully, managed.

In fresh water eels would seem to have relatively few enemies because of their nocturnal habits. However, there is little doubt that young eels contribute to the diet of larger fishes and, occurring as they do in exceedingly large numbers when first arriving from the sea, must be vulnerable to attack at this time. Needler (1929) reported up to 12 elvers per stomach in haddock caught off Cape Breton in May. We have observed a large migrating eel attacked and caught by an osprey and doubtless migrating adult eels fall prey to a variety of large marine species such as sharks and swordfish.

Little has been published regarding the parasites of the American eel in Canadian waters. Van Cleave (1921), working in the eastern United States, examined four species of Acanthocephala from the intestine: *Tanaorhamphus ambiguus* n.sp., *Neoechinorhynchus cylindratus*, *Echinorhynchus coregoni* (originally described from the Great Lakes), and *Echinorhynchus thecatus*. Van Cleave noted that there was no evidence of marine species of Acanthocephala inhabiting the intestine of *A. rostrata*. In 1923 the same author reported relatively large numbers of *E. thecatus* in the digestive tract of the American eel in Oneida Lake, N.Y., and noted that *N. cylindratus* was also present.

In a further study of the parasites in Oneida Lake fishes, Van Cleave and Mueller (1934) stated that the eel was the most important host of the trematode *Azygia longa* found in the stomach, and was also the only significant host of the cestode *Bothriocephalus claviceps*.

The cestode *Proteocephalus macrocephalus* and the nematode *Haplonema* sp. were also reported present in the digestive tract.

Hoffman (1967) listed many species of parasites infecting the freshwater eel in North American waters, including protozoans, trematodes, cestodes, nematodes, acanthocephalans, and crustaceans.

Relation to man Yellow and silver eels are fished commercially in Canada, the most successful fisheries existing along the St. Lawrence River between Trois-Rivières and Cap-Chat in Quebec. The Quebec fishery constitutes about 70% of the eels taken in Canada and these are mainly the prized silver (or bronze) eel. There are smaller fisheries on Lake Ontario around the Bay of Quinte, the northeast shore of New Brunswick, and the southwest coast of Nova Scotia (Eales 1968). Prince Edward Island has a very small fishery and, although attempts were made in Newfoundland to promote a fishery for export of eels to European countries, catches declined and the fishery has been discontinued.

Dr F. M. Atton (personal communication) has drawn to our attention an interesting experiment conducted in 1952. Drs A. G. Huntsman and V. Davidson arranged for the transport of elvers to Saskatchewan by air. About 30 or 40 1.5-inch (40-mm) long elvers were moistened with a tablespoon of water and placed in a pint ice cream box. The ice cream boxes were stacked in a large carton and shipped without temperature control. The elvers were in transit for about 24 hours before release in Saskatchewan. They were planted in a saline lake (461 ppm), (Lac Pelletier, near Swift Current). Dr Atton reported that the young eels survived well, for a number were recaptured 7, 8, and 9 years later, not in the lake but in the water supply reservoir at Swift Current. Others were caught in the South Saskatchewan River, and one was taken in the river at Saskatoon.

In Quebec, eels are taken mainly in weirs; in Ontario baited setlines and fykenets are used, and in the Maritimes they are captured in baited pots, hoops, and occasionally by weirs. The eels in Prince Edward Island are primarily speared. Smith and Saunders (1955) suggested that seaward migrations of eels may have represented major losses of organic matter to lakes.

The 1967 landings for Canada totalled 1,645,000 pounds with a value of $400,000 (Fisheries Statistics of Canada 1967). When exported most eels are shipped frozen.

Large eels find a ready market in England where they are desired alive for jellied eel, and some, cooked in olive oil and vinegar, are preferred by the Italians (Bruemmer 1967). Smoked eel, however, is by far the most acceptable in most countries, and is considered a connoisseur's item.

Eales (1968) gave a detailed account of the Canadian eel fisheries in the various provinces and the export markets.

Nomenclature

Muraena rostrata — LeSueur 1817a: 81 (type locality Cayuga Lake)
Muraena Bostoniensis — LeSueur 1817a: 81
Muraena serpentina — LeSueur 1817a: 81
Muraena argentea — LeSueur 1817a: 82
Muraena macrocephala — LeSueur 1817a: 82
Anguilla chrysypa — Rafinesque 1817b: 120
Anguilla vulgaris — Perley 1852: 219
Anguilla punctatissima — Kaup 1856: 44
Anguilla novaeterrae — Kaup 1856: 45
Muraena anguilla — Fortin 1863: 118
Anguilla Bostoniensis Les. — Adams 1873: 256
Anguilla tenuirostris DeKay — Adams 1873: 256
Anguilla muraena — Montpetit 1897: 261
Leptocephalus grassii — Eigenmann and Kennedy 1902: 84
Anguilla rostrata (LeSueur) — Bailey et al. 1960: 19

Etymology *Anguilla* — the eel; *rostrata* — from *rostratus*, meaning long-nosed.

Common names American eel, Atlantic eel, eel, common eel, freshwater eel, silver eel, easgann, elver. French common name: *anguille d'Amérique*.

Suggested Reading — Anguillidae

ANON. 1963. Eel fishing in Newfoundland. Trade News 15(9): 9.

BERTIN, L. 1956. The world of eels. Eels. A biological study. Cleaver-Hume Press Ltd., London. 192 p.

BRUEMMER, F. 1967. Eeling in Quebec. Can. Audubon 29(1): 11–14.

DAY, L. R. 1948. Fishing eels — a profitable side line. Fish. Res. Board Can., Biol. Sta. St. Andrews, N.B., Gen. Ser. Circ. 13: 3 p.

DEELDER, C. L., and D. W. TUCKER. 1960. The Atlantic eel problem. Nature 185: 589–592.

EALES, J. G. 1968. The eel fisheries of Eastern Canada. Fish. Res. Board Can. Bull. 166: 79 p.

EGE, V. 1939. A revision of the genus *Anguilla* Shaw. A systematic, phylogenetic and geographical study. Dana-Rep. 16: 256 p., 53 fig. and charts, + 6 pl.

FISH, M. P. 1927. Contributions to the embryology of American eel. Zoologica 8: 289–324.

JENSEN, Ad. S. 1937. Remarks on the Greenland eel, its occurrence and reference to *Anguilla rostrata*. Medd. Grønland 118(9): 1–8.

NORMAN, J. R. 1963. A history of fishes. 2nd ed. Revised by P. H. Greenwood. Ernest Benn Ltd., London. 398 p.

SCHMIDT, J. 1922. The breeding places of the eel. Phil. Trans. Roy. Soc. London, Ser. B, 211: 179–208.

1925. The breeding places of the eel. Ann. Rep. Smithson. Inst. 1924. p. 279–316 + 7 pl.

SMITH, D. G. 1968. The occurrence of larvae of the American eel, *Anguilla rostrata*, in the Straits of Florida and nearby areas. Bull. Mar. Sci. 18: 280–293.

SMITH, M. W., and J. W. SAUNDERS. 1955. The American eel in certain fresh waters of the Maritime Provinces of Canada. J. Fish. Res. Bd. Canada 12: 238–269.

TUCKER, D. W. 1959. A new solution to the Atlantic eel problem. Nature 183: 495–501.

VLADYKOV, V. D. 1955. Fishes of Quebec. Eels. Dep. Fish. Que. Album 6: 12 p.

1964. Quest for the true breeding area of the American eel (*Anguilla rostrata* LeSueur). J. Fish. Res. Bd. Canada 21: 1523–1530.

THE KILLIFISHES — Order Cyprinodontiformes (Microcyprini)

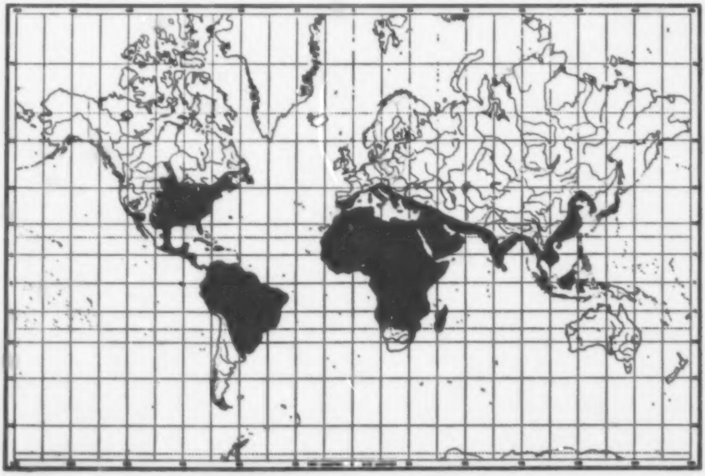
Small, stout-bodied fishes, moderately compressed laterally. Mouth small, terminal, lower jaw often projecting beyond upper; upper jaw bordered by premaxillae; jaws with well-developed teeth; orbitosphenoid and mesocoracoid bones absent. All fins soft rayed, single dorsal often located posteriorly; anal variously modified as an intromittent organ in some groups; pelvics, when present, abdominal; pectorals located in elevated position on sides, the bases approaching vertical orientation; scales cycloid, rarely ctenoid, or absent, on head and body; typically without pored scales of lateral line. Physoclists.

These small fishes are characteristic of tropical or subtropical, marine, brackish, or fresh waters of all continents except Australia. The order contains 8 families and about 400 species. One family, the Poeciliidae, includes many well known live-bearing aquarium fishes. The family Cyprinodontidae occurs naturally in eastern Canadian waters but the family Poeciliidae has been introduced in some restricted localities in Alberta. Oligocene to Recent.

KILLIFISH FAMILY — Cyprinodontidae

Small fishes exhibiting the principal characters of the order. Head often adapted for surface feeding, flattened above; mouth small, terminal, protractile. Branchiostegals 5–7. Gill membranes free from isthmus. Caudal fin squarish or rounded; anal fin not conspicuously modified. Scales cycloid.

Most species of killifishes inhabit freshwater shallows, but many move freely into brackish water and even sea water. They occur in southern Europe, Africa, southeast Asia, and the East Indies but attain greatest development and are most speciose in southeastern United States. The family contains about 45 genera and some 300 species of which two occur in Canadian waters. From Oligocene to Recent.



World Distribution of the Killifishes

Key to Species[1]

1 Gill rakers usually 5, widely spaced and obvious; branchiostegal rays 6,6, never 5,5; distance from origin of dorsal to end of vertebral column, when stepped forward from dorsal fin origin, reaches a point about middle of eye. .... BANDED KILLIFISH, *Fundulus diaphanus* (p. 631)

Gill rakers usually 9 or more, crowded and not obvious; branchiostegal rays 5,5, rarely 6,6; distance from origin of dorsal fin to end of vertebral column, when stepped forward from dorsal fin origin, reaches to posterior half of operculum. .... MUMMICHOG, *Fundulus heteroclitus* (p. 635)

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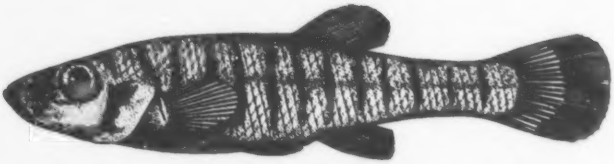
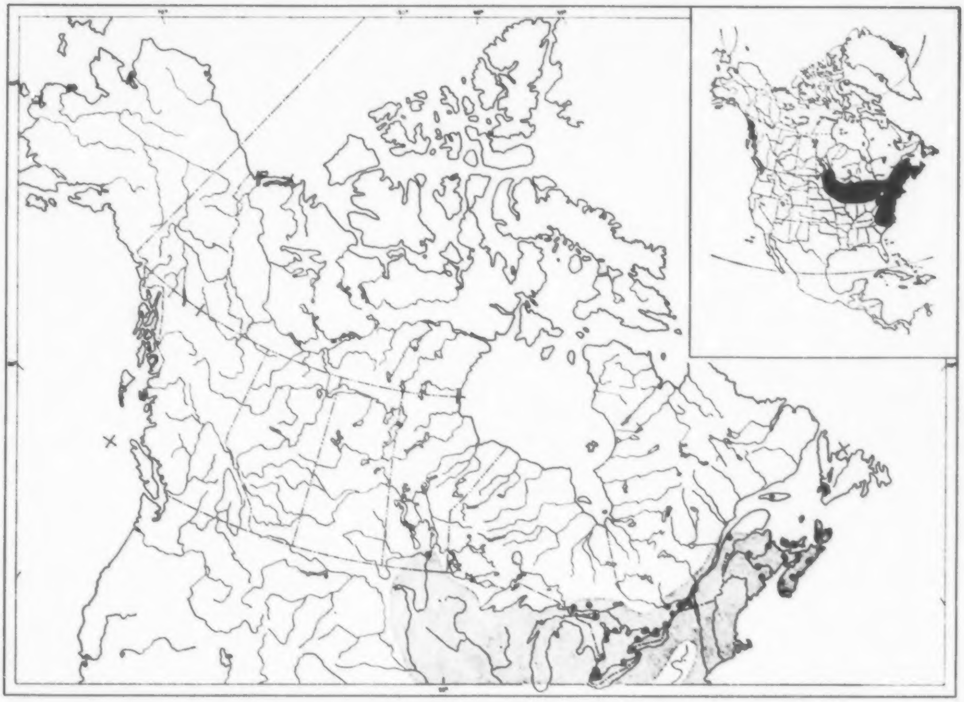
[1] *Fundulus notatus* was reportedly caught in Sydenham River, Ontario in late 1972, after this manuscript had gone to press.

BANDED KILLIFISH

Fundulus diaphanus (Lesueur)



Description Body elongate and slender, somewhat flattened at back of head and nape region, average length about 3 inches (76 mm), greatest body depth 12.9–17.2% of total length. Head bluntly triangular and broad, its length moderate, 21.3–24.2% of total length; eye moderate, its diameter 23.6–31.7% of head length; snout bluntly rounded, its length 30.3–35.7% of head length; interorbital width 29.4–34.9% of head length; mouth opening small and directed upward, lower jaw protruding when mouth closed, teeth on upper and lower jaws only, teeth in outer rows larger than those of inner row, tooth size decreases posteriorly; premaxillaries protractile. Gill rakers small, 4–7 usually 5 or 6. Branchiostegal rays usually 6,6(24), but sometimes 5,6(3), 6,7(1), or 7,7(1). Fins: dorsal 1, its origin distinctly in advance of anal fin origin, rays usually 13(18), sometimes 12(6), 14(8), or 15(2), larger on males than on females; caudal rounded, rays usually 16(38), sometimes 14(3), 15(4), or 17(3); anal 1, its origin distinctly posterior to dorsal fin origin, rays 11(19), 12(13), or 13(1), larger on males than on females; pelvics abdominal, small, rounded, rays 6(52); pectorals rounded, paddle-like, rays variable but usually 16(23), sometimes 14(6), 15(4), 18(2), or 19(1). Scales cycloid, in 40–51 rows on body, counting from upper end of gill opening, variable



but usually 43–49; lateral line pores on head only, none on body (see *F. heteroclitus*). Peritoneum silvery and lightly speckled, not uniformly black; intestine with single loop, about one-half body length. Vertebrae usually 34(14), but sometimes 33(2), 35(5), or 36(4).

Colour The overall colouration is brown or dark brown to olive-green on the back, becoming silvery or yellow-silvery on the sides and white or yellowish white below. There are usually 12–20 vertical bars on the sides (fewer and more widely spaced on females), which are quite apparent on dead or preserved specimens but may be rather inconspicuous on living ones. The overall colouration, including the vertical bars, dorsal, and anal fins, is enhanced on males during spawning. The dorsal fin, in particular, may exhibit green-gold iridescence and a suggestion of a band or two of black pigment.

Systematic notes Two subspecies have been described, both of which occur in Canada. The eastern banded killifish *F. d. diaphanus*, occurs in the Atlantic drainage of Canada westward to eastern Lake Ontario and the upper St. Lawrence River, where it intergrades with the western form *F. d. menona*.

Hybridization is apparently rare, but Hubbs et al. (1943) described a single specimen, a hybrid, apparently the product of a mating between *Fundulus d. diaphanus* and *F. heteroclitus macrolepidotus*, caught in Lake of Shining Waters, P.E.I., by M. W. Smith in 1939. Breder and Rosen (1966) noted that Newman (1914) had more success experimentally hybridizing *F. diaphanus* and *F. heteroclitus* than any other *Fundulus* spp.

Distribution The banded killifish occurs from South Carolina north to the Maritime Provinces and Newfoundland; west through New York, Pennsylvania, and southern Canada in the Great Lakes basin, to the Yellowstone River in eastern Montana.

In Canada, it is rather widely distributed in the Maritime Provinces but is known from only a few localities in southwestern Newfoundland; through the St. Lawrence valley of Quebec in suitable habitats; through the Great Lakes watershed of southern Ontario, excluding Lake Superior (excepting extreme eastern Lake Superior in Michigan waters). It was reported only once from the Red River of Manitoba (Stewart-Hay 1954), but there apparently have been no subsequent captures.

Biology One of the few observers to record the spawning behaviour of the banded killifish was Richardson (1939), whose observations were made on a tributary of the Richelieu River near Iberville, Que. Richardson's fish spawned in aquaria during the last week of May, 1935, at a temperature of 73.4° F (23° C), although prespawning activities became apparent at 69.8° F (21° C).

In the wild, the males selected breeding areas in the quiet waters of weedy pools. These areas were defended vigorously. Fights between rival males were common, but Richardson described them as not vicious nor damaging. The males assumed their most intensive bluish-green colouration, but the females remained pale. In aquaria, males and females eventually paired off according to size, each male pursuing an individual female. The genital papilla of the female enlarged and protruded obviously during the pursuit, and after several minutes the female extruded a single egg. The single egg remained suspended by a fine translucent thread, about an inch below the papilla. The male then pursued even more vigorously, driving the female into a cluster of weeds, pressing his body closely against hers and holding her in this position by using the dorsal and anal fins, rather in the manner described for *F. heteroclitus*. The female exuded additional eggs, in clusters of 5–10. The male's body quivered rapidly and assumed a bow shape, and it was at this time that milt was released and fertilization occurred. Richardson noted that on fertilization the eggs usually separated from the cluster, became detached from the thread, and, falling into the weeds, became entangled by their individual threads which appeared to be quite adhesive. If the egg cluster failed to break up, it was usually caught in the weeds and pulled free of the female as she swam away. The whole mating performance required 15–30 seconds and was repeated several times over a period of about 5 minutes until about 50 eggs were deposited by each of the pairs under observation in the aquaria.

Egg diameters were not noted by Richardson (1939) but Cooper (1936a) gave a diameter of 2.0 mm for eggs taken in a hatchery pond in Michigan. These latter hatched in 11–12 days at water temperatures of 72°–80° F (22.2°–26.7° C), yielding fry 6–7 mm long. Cooper (1936a) found eggs only among filamentous algae. Larval stages of 7.1 mm and 12.3 mm, total length were described and illustrated for Lake Erie specimens by Fish (1932).

Critical growth studies appear to be unavailable. From a length of 6–7 mm, on hatching, young banded killifish may attain a total length of 0.8–2.3 inches (20–58 mm) by October of their first year in Ohio (Trautman 1957); or total lengths of 1.3–2.5 inches (33–64 mm) at age 1 in Gibson Lake, N.B., (Smith 1952). Adult sizes usually range from 2.5–3.0 inches (64–76 mm) total length in inland waters, but larger sizes are common in the Maritime Provinces. In Wheaton Lake, N.B., adult females over 3 inches (76 mm) are common, and from Lake O'Law, Inverness County, N.S., there are specimens in the ROM collection over 4 inches (102 mm) total length, and one measured 4.5 inches (114 mm) total length. This is possibly the largest size reported for the species in Canada.

The banded killifish prefers the quiet waters of lakes and ponds. Small schools are usually found over sand, gravel, or detritus-covered bottom where there are patches of submerged aquatic plants. The schools tend to stay in sand-bottomed shallows.

Keast and Webb (1966) worked on Lake Opinicon, Ont., and noted that the species fed as a member of a school. The individuals are versatile feeders, are rather generalized in their food and feeding habits, and feed effectively at all levels despite the dorsal position of the mouth. Small killifish of 1.2–1.6 inches (30–40 mm) total length ate mainly chironomid larvae (at times up to 60% by volume), ostracods (to 35%), cladocerans (to 25%), copepods (to 30%), and smaller amounts of amphipods and flying insects. Adults of 2.4–3.2 inches (60–80 mm) total length ate the same items as the smaller fish but in addition consumed newly hatched Odonata and Ephemeroptera nymphs, molluscs, and turbellarians. It was the only species in the lake to feed on ostracods to a significant degree.

The banded killifish may serve as an important food of game fish, whenever it occurs in sufficient numbers. It also formed an important part of the diet of the kingfisher and the American merganser in the Maritime Provinces (White 1953, 1957).

Bangham and Hunter (1939) examined 31 specimens of *F. d. menona*, and found 13 infected. Parasites listed were the trematode *Neascus vancleavei*, nematodes *Agamonema* sp., and *Rhabdochona* sp., protozoan Myxosporidia, and the larval or immature forms of the cestode *Proteocephalus* sp., and of the acanthocephalan *Neoechinorhynchus* sp.

Hoffman (1967) listed protozoans (1), trematodes (14), cestodes (1), nematodes (1), and acanthocephalans (2), from the banded killifish in North American waters.

Relation to man Banded killifish are sometimes used as live bait in parts of Nova Scotia and New Brunswick, for it is hardy and may survive for many hours in a minnow pail. It is also said to live for many hours packed in leaves in a tin can. Livingstone (1953) reported that it could live this way, without water, for several days. It must indeed be a hardy species!

Nomenclature

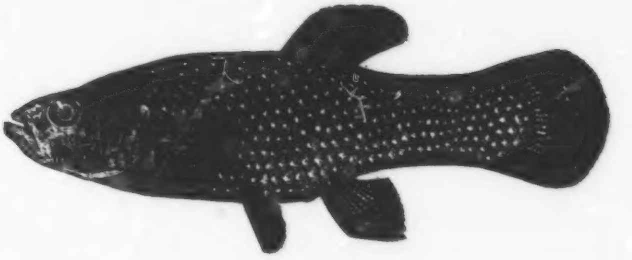
Hydrargira diaphana — LeSueur 1817e: 130 (type locality Saratoga Lake, N.Y.)
Hydrargira Multifasciata — Small 1865: 35 (abundant in the St. Lawrence River)
Zygonectus diaphanus (LeSueur) — Jordan, Evermann, and Clark 1930: 178
Fundulus extensus — Hubbs 1931: 3
Fundulus diaphanus — Nash 1908: 71

Etymology *Fundulus* — *fundus*, meaning bottom, the abode of the "Fundulus mudfish"; *diaphanus* — transparent.

Common names Banded killifish, eastern and/or western banded killifish, freshwater mummichog, fresh-water killy, grayback, freshwater killifish, killifish, topminnow, minnow, menona killifish, barred minnow. French common name: *fondule barré*.

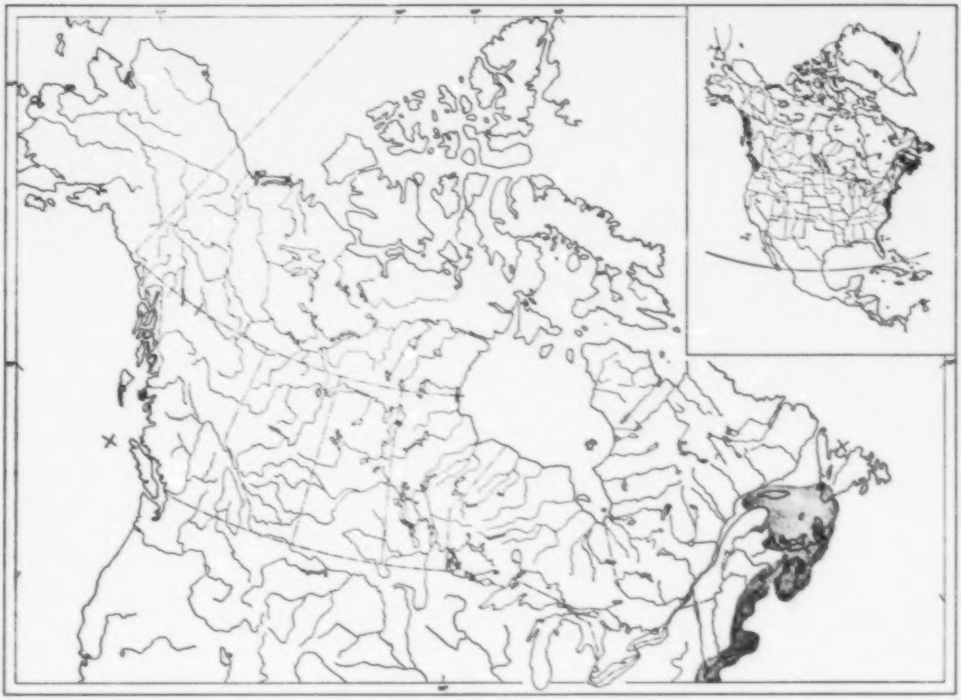
MUMMICHOG

Fundulus heteroclitus (Linnaeus)



Description Body generally robust and rather thick but elongate, somewhat flattened at back of head and nape region, size small, average length about 3 inches (76 mm), with a deep caudal peduncle, greatest body depth 15.8–20.0% of total length. Head moderate, bluntly triangular, and broad, its length 20.6–25.0% of total length; eye moderate, its diameter 21.6–28.3% of head length; snout bluntly rounded, its length 26.6–34.1% of head length; interorbital width 33.3–44.0% of head length; mouth opening small and directed upward, lower jaw protruding when mouth closed; teeth on upper and lower jaws only, teeth in outer row longer, those of inner row shorter, longest teeth at median position of upper jaw, becoming shorter posteriorly; premaxillaries protractile. Gill rakers small, 8–12, usually 9–11. Branchiostegal rays usually 5,5(26), but some variability, 5,4(1); 4,5(1); 6,6(8); 5,6(3). Fins: dorsal 1, its origin slightly in advance of anal fin origin, rays 11(26) or 12(37), seldom 10(1) or 13(5), larger in males than females; caudal rounded, rays usually 18–20(37), sometimes 17(2), 21(10), or 22(5); anal 1, its origin slightly posterior to dorsal fin origin, rays usually 11(21), sometimes 9(2), 10(15), or 12(1), larger on males than females; pelvics abdominal, small, rounded, rays usually 6(56), sometimes 7(12); pectorals rounded, short, paddle-like, rays usually 18(32) or 19(29), sometimes 16(1), 17(4), or 20(3), (for details of fin regeneration, *see* results of experimental work by Goss and Stagg 1957). Scales cycloid, in 32–38 rows on body, counting from upper end of gill opening usually 34–36; scales on males with contact organs during mating season (*see* Newman 1907); lateral line pores on head only, no lateral line on body (*see* Denny 1938; and Van Bergeijk and Alexander 1962). Peritoneum uniformly black. Vertebrae usually 33(25) but sometimes 32(7), 34(6), or 35(1).

Colour Highly variable depending on age, sex of individuals, and local conditions, but overall colour is olive-brown, olive-green to pale green or almost tan. Young fish are usually lighter in colour with few vertical bars, while older ones are darker, with numerous but often poorly defined silvery vertical bars. Males colourful, especially in spring spawning dress, with olive-green over the back and upper parts of sides, about 15 wavy, silvery, vertical bars on sides, more distinct posteriorly, steel-blue hue on sides, ventral surfaces are strongly yellow or orange-yellow. The ventral surface of head and body, including pectoral, pelvic, and anal fins suffused with yellow; dorsal fin with mottled appearance (*see* Parker and Brower 1935) and often with an oblong black blotch, with a whitish margin on upper portion of posterior rays of dorsal fin; mature males have also a



small yellow spot on the back at the origin of the dorsal fin. Adult females are more uniformly olive-green to light olive in colour and lack the intense yellow on ventral surface, and the dorsal fin is uniformly pigmented but never with mottled or black markings.

Many authors have remarked upon the unusual ability of the killifishes, especially *F. heteroclitus*, to change colour in response to changes in background colour.

Systematic notes A number of subspecies of *F. heteroclitus* have been described but their present status is not clear. The typical subspecies, *F. h. heteroclitus*, is said to range from northeastern Florida to about Virginia. *F. h. macrolepidotus* ranges from Virginia north to the Gulf of St. Lawrence and southern Newfoundland, and is, therefore, the form occurring in Canadian waters.

Examples of hybridization involving *F. heteroclitus* are rare but Hubbs et al. (1943), described in detail a single, adult female, *Fundulus diaphanus diaphanus* × *F. h. macrolepidotus* taken in Lake of Shining Waters, P.E.I., by M. W. Smith in 1939.

Sexual dimorphism is exhibited by both colour and size of dorsal and anal fins; the male is the more colourful and has a variously mottled dorsal fin and both dorsal and anal fins of males are larger and better developed than those of females.

Babkin and Bowie (1928) demonstrated that the species does not have a stomach in the classical sense; that is, it does not have an organ that secretes pepsin–hydrochloric acid, but has the intestine (duodenum) joined directly to the oesophagus, a situation similar to that found in the Cyprinidae.

Distribution The mummichog occurs in Atlantic coastal and brackish waters from northeastern Florida to the Gulf of St. Lawrence region. It occasionally enters freshwater streams and rivers.

In Canada it occurs throughout the shore waters of all of the Maritime Provinces to the Port au Port Bay region of southwestern Newfoundland, in all suitable waters but particularly in estuaries and salt marshes, west in the Gulf of St. Lawrence to Anticosti Island and both shores of Quebec, upriver to about the head of tide.

Biology Many observers have reported on the spawning activities of the mummichog but one of the earliest and most comprehensive accounts was that of Newman (1907), based on populations in the vicinity of Woods Hole, Mass. Spawning takes place in the spring and summer but the commencement and duration of spawning is significantly affected by temperature (Brummett 1966). In the New England region it is said to spawn in June, July, and early August, although Brummett noted that spawning at Woods Hole was usually limited to June and the first 2 weeks of July.

Courtship and spawning behaviour were also described in detail by Newman (1907) who noted that the male was active and aggressive in courtship, but that females also attracted males by turning on their sides near bottom and flicking their tails. No nest was prepared. Pairs of males and females swim about, the female slightly above, the male below and slightly behind the female. He observed that a spawning male will eventually crowd a ripe female against a reasonably solid object such as a rock or stone, his whole body in contact with hers, head to head, and tail to tail. It is presumably at this time that the contact organs function. These are fingerlike processes on the scale margins which Newman described and illustrated. The female's body was so curved that only the head and a central portion of the body were in contact with the object. The male held the female in this position by using his larger dorsal and anal fins as claspers, sliding them under the homologous fins of the female and folding them around her body. This position was usually assumed near bottom and the female was often supported from the bottom by her anal fin which sometimes became inflamed from frequent contact with the bottom substrate. The male was usually in contact with the female for one to two seconds during which time a quivering vibration occurred and both eggs and sperm were extruded by the spawning pair. Newman believed the vibration originated with the female since he observed females in aquaria exhibiting vibrations during the emission of eggs in the absence of males. The eggs are extruded through a tube on the anterior margin of the anal fin (Bertrand 1893) and appear to drop off the anterior tip of the fin. The eggs are usually pale yellow in colour and about 2 mm in diameter. Katz (1954) recorded 460 eggs from one female. On extrusion, they become adhesive and may stick together or become attached to bottom materials. They are said to hatch in 24 days at 55°–63° F (12.8–17.2° C), according to Ryder (1886), and in 9–18 days, depending on temperature (Bigelow and Schroeder 1953). The larvae are 7.0–7.7 mm long on hatching, according to Bigelow and Schroeder, who noted further that the dorsal and anal fins are fully developed at lengths of 11 mm, the pelvic fins at 16 mm, and that by 20 mm the young resemble their parents. Scales first appear about the pectoral fins when young are 12.4–12.7 mm long.

The remarkable hardiness of the eggs has been discussed at length by Stockard (1909, 1910), and Chidester (1916).

Although the mummichog has been widely used in experimental studies, little attention has been paid to growth and, hence, data on rates of growth are not available. Maximum size attained in the Canadian area is about 5.1 inches (130 mm). Fish of this size have been reported by Needler (1939) from Prince Edward Island, and we have specimens of this size from the Magdalen Islands, both localities in the Gulf of St. Lawrence. Possibly mummichogs grow larger in the Gulf of St. Lawrence than elsewhere in the Canadian region for Bigelow and Schroeder (1953) reported that adults seldom exceed 3.5—4.0 inches (89–102 mm) in length in the Gulf of Maine.

Mummichogs occur most commonly in salt marsh flats, estuaries, and tidal areas, especially where there is submerged or emergent vegetation. Although it is primarily a salt and brackish water form (Needler 1939, reported that it was one of the most abundant species in Malpeque Bay, P.E.I.), it may also occur in freshwater. Klawe (1957) reported such a population in a freshwater lake on Digby Neck, N.S. It appears to be tolerant of a wide range of salinities and also temperatures. Garside and Jordan (1968) presented comparative lethal temperature data indicating that the upper lethal temperature for the mummichog was 93.0° F (33.9° C) at 14‰ salinity.

The mummichog, in common with other cyprinodont fishes, has a flattened head and a mouth that opens dorsally, which are adaptations for surface feeding. Nevertheless, available information indicates that this is an omnivorous feeder, but detailed food studies are unavailable, at least for the Canadian region. Among the items found in their digestive tracts are diatoms, amphipods, and other crustaceans, molluscs, fish eggs and small fishes, and also vegetation such as eel grass. Newman observed that females would quickly devour their own eggs, or those of other females, given the opportunity.

The scattered records available suggest that a variety of other creatures prey on mummichogs, due in part to the availability of this species in schools in shallow inshore waters. Dr M. W. Smith reported that freshwater mummichogs were found in the stomachs of otter, mink, brook trout, and bullfrogs (White et al. 1965). Mummichogs were also reported as food of kingfishers by White (1953) particularly in Northumberland Strait and Prince Edward Island region. Mention has already been made of cannibalistic tactics of females devouring their own eggs.

White el al. (1965) raised the question of the toxicity of mummichogs when eaten by other animals, suggesting that there are grounds for suspicion, but to our knowledge, no further work has been attempted.

An unidentified species of the endoparasitic trematode *Distomum* was reported from the stomach and intestine by Stafford (1907), who worked at St. Andrews, N.B. A monogenetic trematode, *Gyrodactylus* sp., (family Gyrodactylidae) was described as a serious parasite of the mummichog in the region of St. Andrews, N.B., and Halifax, N.S., by Gowanlock (1927).

Hoffman (1967) listed the following parasites from the mummichog in North American waters: protozoans (10), trematodes (8), nematodes (1), acanthocephalans (1), and crustaceans (2).

Relation to man The mummichog has been a popular laboratory animal for embryological, and a wide variety of physiological, studies for many years, and was first used for experimental work in the late 1800's. Its hardiness, when held under artificial conditions, and the relative ease with which it can be captured, have contributed to its popularity. For the same reasons, the species is used to some extent as live bait by anglers, being known as "salt water minnows." Livingstone (1953) reported that successful air shipments of mummichogs from Halifax to central Canada have been made by commercial bait dealers.

As noted previously, White et al. (1965) drew attention to the possibility that mummichogs may be poisonous when eaten by other animals but the suspicion has not been investigated.

Nomenclature

Cobitis heteroclita — Linnaeus 1766: 500 (type locality Charleston, S.C.)
Fundulus fasciatus — Perley 1852: 194
Fundulus pisculentus Val. — Adams 1873: 306
Fundulus nigrofasciatus (LeSueur) — Cox 1896b: 67
Fundulus heteroclitus (Linnaeus) — Jordan and Evermann 1896–1900: 640

Etymology *Fundulus* — *fundus*, meaning bottom, the abode of the "Fundulus mudfish"; *heteroclitus* — irregular or unusual.

Common names Mummichog, common killifish, salt water minnow, mummy, chub (Miramichi River and environs), common mummichog. French common name: *choquemort.*

Suggested Reading — Cyprinodontidae

CONNOLLY, C. J. 1925. Adaptive changes in shades and color of *Fundulus*. Biol. Bull. (Woods Hole) 48: 56–77.

HUBBS, C. L. 1931. Studies of the fishes of the order Cyprinodontes. X. Four nominal species of *Fundulus* placed in synonymy. Occas. Pap. Mus. Zool. Univ. Mich. 231: 8 p.

RICHARDSON, L. R. 1939. The spawning behaviour of *Fundulus diaphanus* (LeSueur). Copeia 1939: 165–167.

SCOTT, W. B. 1967. Freshwater fishes of eastern Canada. 2nd ed. Univ. Toronto Press, Toronto, Ont. 137 p.

SMITH, M. W. 1952. Limnology and trout angling in Charlotte County lakes, New Brunswick. J. Fish. Res. Bd. Canada 8: 383–452.

TRAUTMAN, M. B. 1957. The fishes of Ohio with illustrated keys. Ohio State Univ. Press, Columbus, Ohio. 683 p.

THE CODLIKE FISHES — Order Gadiformes (Anacanthini)

The gadiforms are stout-bodied, elongate fishes, only moderately laterally compressed; the head is relatively large, the skull elongate, low, and composed of thin bones; the numerous small teeth are set in weak jaws, the upper jaw bordered by premaxillary only. A median, mental (or chin) barbel is often present. Branchiostegal rays 5–8. The fins are all soft rayed; there may be 1, 2, or 3 dorsal fins and 1 or 2 anal fins; the caudal fin is supported by the neural and haemal spines of the posterior vertebrae, not by an expanded hypural plate; pelvic fins of 5–17 rays, thoracic, or jugular in position, sometimes filamentous, and located below or in advance of the pectoral fins, the pelvic bones being attached to the cleithra by ligaments only or directly. Physoclists. Caudal vertebrae becoming smaller posteriorly; posterior vertebrae not upturned.

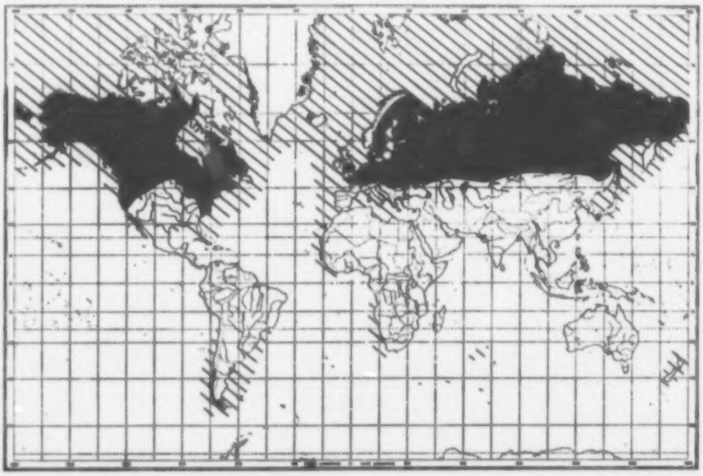
The gadiform fishes are widely distributed in cool seas. The order is classified in 5 families and about 400 species. Only one family, Gadidae, is represented in Canadian fresh waters.

Cod Family — Gadidae

The cods have large heads, wide gill openings, jaws terminal or nearly so, both jaws and vomer equipped with numerous small teeth in wide bands; a slender barbel located at tip of chin. Scales small, cycloid. Swim bladder with projections anteriorly. First vertebra attached to skull.

The Gadidae are primarily marine, bottom-dwelling fishes occurring in cool seas principally in northern latitudes but a few species are known to occur in the seas of the southern hemisphere.

The family is classified in 3 subfamilies, Lotinae, Merluccinae, and Gadinae, which contain approximately 60 species. Two species have been recorded from Canadian fresh waters — *Lota lota*, which has a circumpolar distribution, the only truly freshwater species, and *Microgradus tomcod*, a marine species that seasonally invades fresh waters on the eastern seaboard and has become landlocked in a few lakes in the Atlantic Provinces.



World Distribution of the Cods

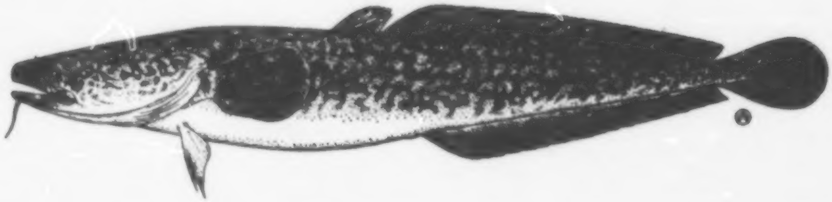
KEY TO SPECIES

1 Two dorsal fins, base of first short, length of base of second 6 or more times that of the first; 1 anal fin .... BURBOT, *Lota lota* (p. 641)

Three dorsal fins, bases of near equal length; 2 anal fins .... ATLANTIC TOMCOD, *Microgadus tomcod* (p. 646)

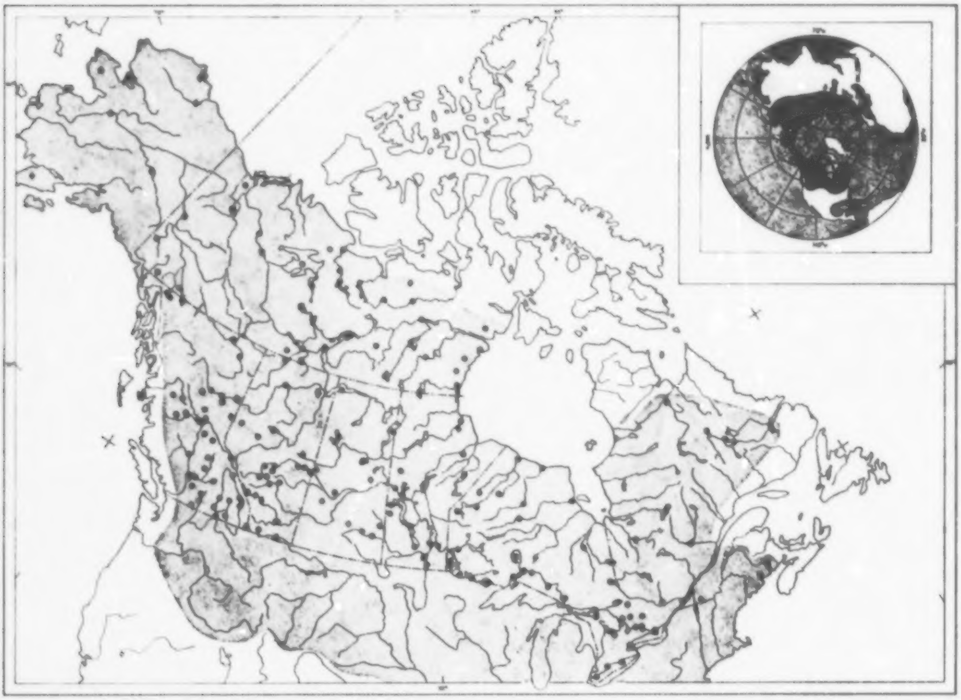
BURBOT

Lota lota (Linnaeus)



Description Body elongate, robust, average length about 15 inches (381 mm); anterior to anus it is nearly round in cross section, the body width to body depth ratio about 1:1, sometimes wider than deep for large adults; posterior to anus body distinctly compressed laterally. Head triangular, broad, depressed, its length 19.2–19.9% of total length; eye small, its diameter 11.2–16.4% of head length; snout projecting, of moderate length 27.5–32.5% of head length; one tube or barbel-like extension for each nostril opening, each about ¼ the length of chin barbel; interorbital broad, its width 27.9–31.9% of head length; mouth rather large, slightly subterminal, maxillary extending to below orbit; teeth in jaws and vomer slender, and in many rows, no teeth on tongue or maxillaries; a slender barbel on tip of chin, its length 12.5–29.9% of head length, higher values for large fish. Gill rakers 7–12. Branchiostegal rays 7, rarely 8. Fins: dorsals 2; first dorsal low, short, rays 8–16; second dorsal low, base long, extending onto caudal peduncle and joined to caudal fin, rays 60–79; height of first dorsal and second dorsal about 25% of head length; caudal rounded, joined to second dorsal and anal fins, a deep notch separating fins, but there is no free caudal peduncle; anal long and low, lower than dorsals, rays 59–76; pelvic fins jugular, inserted in advance of pectorals, rays 5–8, second ray prolonged; pectoral fins rounded, short, paddle-like, rays 17–21. Scales cycloid, small, embedded, 27–29 between second dorsal and lateral line, embedded scales on integument on base of fins; lateral line complete. Pyloric caeca 31–150. Vertebrae 50–66.

Colour In the lower Great Lakes region overall colouration of adults yellow, light brown, or tan, becoming darker northward; the background colour is overlaid by a



lacelike pattern of dark brown or black; at times, especially in inland lakes, adults may be uniformly dark brown or black. On young fish, 1.6–3.6 inches (40–90 mm), the speckled pattern is conspicuous and a dark pigmented margin may occur on the posterior portion of the second dorsal and sometimes on the anal, whereas on the caudal the pigmentation does not extend to the outer margin of the fin.

Systematic notes Hubbs and Schultz (1941), in a study of northwestern North American fishes, described *Lota lota leptura* as a new subspecies, found in northwestern North America and western Siberia, distinct from *Lota lota lota* of Eurasia and *Lota lota maculosa* of eastern North America. Subsequently, the name *L. l. maculosa* was reversed to *L. l. lacustris* (Speirs 1952). Studies by Lindsey (1956), Lawler (1963), and McPhail and Lindsey (1970) have shown some evidence of clinal variation. Hence, in the present state of our knowledge, the recognition of subspecies seems unwarranted.

Distribution The burbot is generally distributed, in all suitable habitats, in the fresh waters of continental Eurasia and North America, southward to about 40°N. It is absent from the Kamchatka Peninsula of eastern USSR, from Scotland, Ireland, and most islands, and from the west coast of Norway. It is present in southern England and on Kodiak Island, Alaska.

In Canada this species occurs in New Brunswick, Labrador, Quebec, throughout Ontario, Manitoba, Saskatchewan, Alberta, and the continental portion of the Northwest and Yukon territories, exclusive of the northernmost tips, to central and eastern British Columbia. It is absent from Nova Scotia and the Atlantic islands.

Biology The burbot is one of the few Canadian freshwater fishes that spawns in midwinter, under the ice. It spawns from November to May over the whole of its world distribution, but mainly from January to March in Canada. There is circumstantial evidence that burbot spawn in deep water in some areas but the spawning site is usually in 1–4 feet of water over sand or gravel bottom in shallow bays, or on gravel shoals 5–10 feet deep. Although they usually spawn in the lake they are also known to move into rivers to spawn. Male burbot arrive on the spawning grounds first, followed in 3 or 4 days by the females. The actual spawning activity is said to take place in a writhing ball about 2 feet in diameter, which moves over the bottom and is made up of 10–12 intertwined and constantly moving individuals. This activity takes place only at night and the grounds are deserted in the daytime. Surface temperature of the water during the spawning period is usually 33°–35° F (0.6°–1.7° C); no nest is built by this species and no care is given the young. Average diameter for the semipelagic eggs of burbot has been recorded as 0.5 mm in Manitoba (before extrusion) but 1.25 mm in Minnesota and 1.77 mm in Ontario. Egg number (calculated) increases from about 45,600, in a 343-mm female, to 1,362,077, for a 643-mm female weighing 6.1 pounds. Eggs hatch in 30 days at 43° F and the young, therefore, appear from late February to June.

Growth in the first 4 years of the burbot's life is relatively rapid but after that time there is a gradual decrease in length increment and increase in weight. The young attain a length of 3.0–8.25 inches (76–210 mm) by the end of the first growing season. At age 5 (by otoliths) burbot in Lake Simcoe, Ont., average about 21.5 inches (546 mm) long and weigh 2–3 pounds. The maximum size in that lake was a 13-year-old female, 32.9 inches (838 mm) total length and 9.5 pounds. There is a growth differential between the sexes and at 4 years of age females become significantly longer than males; this condition prevails. The length–weight relation in Manitoba is log W=2.52+3.164 log L, where W=weight in ounces and L=total length in inches. Sexual maturity in the burbot is usually attained during the third or fourth year between 11.0 and 18.9 inches (280–480 mm), but males often mature at a smaller size.

The following comparison of age–length relations reveals that growth rate for the species increases from Manitoba through Ontario to its highest in Lake Erie.

	Heming L., Man. (Lawler 1963)	L. Simcoe, Ont. (McCrimmon & Devitt 1954)	L. Erie, Ont. (Clemens 1951b)
Age	Avg TL (*mm*)	Avg TL (*mm*)	Avg SL (*mm*)
1	147	165	210.0
2	246	305	322.7
3	279	432	376.5
4	323	483	424.0
5	366	546	492.1
6	399	572	539.9
7	429	635	557.8
8	465	673	579.1
9	–	737	590.6
10	–	762	616.0
11	–	787	–
12	–	812	–
13	–	837	–

It would appear that the maximum size known for burbot in Canada is 38.3 inches (937 mm) fork length and 18.5 pounds from Great Slave Lake. Elsewhere in the world, the species is reported to attain lengths in excess of 46 inches (1200 mm) and a weight of 75 pounds. Maximum age in Canada is probably between 10 and 15 years.

In central and southern Canada the burbot is usually a resident of the deep waters of lakes whereas in northern Canada it is also present in large, cool rivers. It has been taken as deep as 700 feet and throughout the summer is restricted to the hypolimnion. Optimum temperature for this species is 60°–65° F (15.6°–18.3° C) and 74° F (23.3° C) would appear to be its upper limit. Burbot move into shallower water during summer nights when they are active and in certain areas they definitely move into shallower water to spawn. Also, there is often a post-spawning movement into tributary rivers during late winter and early spring. During this period of concentration they are sometimes readily caught in large numbers. In the north, summer habitat is often in the river channels of lakes and young-of-the-year and yearling burbot are frequently found along rocky shores and sometimes in weedy areas of tributary streams. All movement seems to cease by July and the large fish penetrate to the deep water where adult burbot share the hypolimnic habitat with lake trout, whitefishes, and sculpins.

The burbot is a voracious predator and night feeder. Small burbot, 2–12 inches (51–305 mm) in length, in streams feed on *Gammarus*, mayfly nymphs, and crayfish. The diet of young burbot, to approximately 19.7 inches (500 mm) in length, consists mainly of immature aquatic insects, crayfish, molluscs, and other deepwater invertebrates, especially *Mysis relicta*, but relatively few fishes. Burbot over 19.7 inches (500 mm) long feed almost exclusively on fishes such as ciscoes, yellow walleye, yellow perch, alewife, kokanee, smelt, sculpins, trout-perch, sticklebacks, freshwater drum, logperch, and white bass, depending on what species are available. In summer large burbot sometimes feed exclusively on *M. relicta* in rivers, and the winter food of adults consists of invertebrates browsed from the bottom, even though (presumably) fish are as available as in the summer. Burbot captured on cisco spawning grounds are often gorged with cisco eggs. The literature contains many detailed analyses of the food of burbot (Van Oosten and Deason 1938; Clemens 1951a; McCrimmon and Devitt 1954).

Since the burbot shares the hypolimnion with such commercially important species as lake trout and the whitefishes, since it eats the same food, and since individual burbot have been reported to consume as many as 179 fish, it is an important direct competitor of these species. Of the deepwater fauna it would appear that the burbot is a predator only on eggs and young of the cisco. In the Susquehanna River, of the northeastern United States, where burbot occur with large numbers of brown and brook trout, it was considered a negligible predator of these sport fishes. In their turn young burbot are known to be part of the food of smelt, yellow perch, and other fishes.

In general, burbot harbour a wide variety of parasites including protozoans, trematodes, cestodes, nematodes, acanthocephalans, leeches, molluscs, and crustaceans. The burbot, throughout its range of distribution, is one of the important second intermediate hosts of *Triaenophorus nodulosus*. Detailed accounts of the parasites found in or on burbot from various parts of Canada have been published by Bangham and his co-workers: for Lake Erie by Bangham and Hunter (1939), for Algonquin Park lakes by Bangham (1941), Lake Huron and Manitoulin Island by Bangham (1955), and from British Columbia by Bangham and Adams (1954).

For a summary of parasites of this species in North America, *see* Hoffman (1967).

Relation to man In Canada the burbot populations are not exploited commercially and the species is almost universally regarded as a coarse fish by management agencies and fishermen alike. Records of commercial catches are not usually entered in statistical summaries (except in Ontario) and thus current or potential yields are difficult to assess. The species may occur in considerable numbers in inland waters but not in the Great Lakes where conditions have changed drastically in recent years. The writings of Dymond (1926), Dymond et al. (1929), and Kolbe (1944), among others attested to the former abundance of the burbot and also that it was once considered to constitute a serious nuisance to the commercial fishery in the Great Lakes. In other Canadian lakes it is sometimes thought to be a serious predator of more valuable species and to compete with such species for food.

Provincial agencies engaged in coarse fish removal programs occasionally harvest burbot from inland lakes during the winter months. One such operation in Manitoba (Anon. 1964), using trapnets, yielded 50,000 pounds of burbot in 3 days' fishing, indicating that high yields may be obtained if the fish are harvested during the winter months, when concentrated because of spawning activities.

Although the white, flaky flesh is palatable and nutritious it is not highly esteemed in most parts of Canada and even early reports concerning its palatability are often contradictory. As early as 1836, Richardson stated that the "flesh was eaten only in times of great scarcity . . . ," although Melvill (1915) noted that along the east coast of James Bay the flesh was considered to be excellent for food purposes by both Europeans and Indians. In Wyoming it was said by Bjorn (1940) to have long been regarded as a source of food. Nevertheless, attempts to encourage public acceptance of the burbot in Canada as a quality food fish or processed for industrial use have not been very encouraging to date.

When available in sufficient quantities burbot may be used for animal food on fur ranches and in the production of fish meal and oil. The vitamin A potency of burbot liver oil is stated to be about 500 units or more per gram and analyses of the Vitamin D potency of the oil obtained from the large liver have shown it to be as good as that obtained from cod liver (Branion 1930). When the burbot was abundant in Lake Erie, poundnet fishermen, who regularly handled tar-soaked netting, sometimes used the liver oil on their hands as a protection against the ravages of the tar. Burbot livers are eagerly sought in many European (especially Scandinavian) countries and are a valuable commodity when smoked and canned. Heavy infections of *T. nodulosus* in the liver however often prohibits this use. The Fisheries Research Board of Canada has experimentally canned Canadian burbot livers and the product is considered to be of high quality especially for such use as the making of canapes.

In Canada the burbot is caught incidentally by anglers while "ice-fishing" for lake trout. In recent years fishing through the ice for burbot has become a popular sport in some areas of British Columbia and in the state of Wyoming (Simon 1946), and in the latter case a closed season has been established. In parts of Europe and Asia the subspecies *L. l. lota* is a recognized food fish and is commercially exploited.

Nomenclature

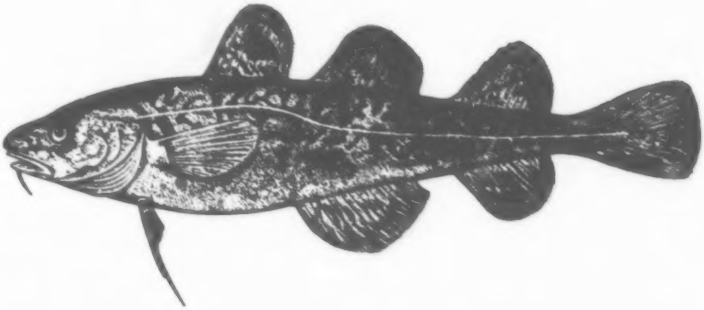
Lota lota — Linnaeus 1758: 255 (type locality Europe)
Gadus Lota Linn. — Forster 1773: 152
Gadus lacustris — Walbaum 1792: 144
Gadus maculosus — LeSueur 1817b: 83
Gadus (Lota) maculosus (Cuvier) — Richardson 1836: 248
Lota maculosa (LeSueur) — Jordan and Evermann 1896–1900: 2550
Lota lota maculosa (LeSueur) — Hinks 1943: 85
Lota lota (Linnaeus) — Dymond 1947: 32
Lota lota lacustris (Walbaum) — Speirs 1952: 100

Etymology *Lota* — the ancient name used by Rondelet.

Common names Burbot, American burbot, ling, eelpout, loche, freshwater cod, maria (Saskatchewan, Manitoba, northern Ontario), methy (northern Canada), lush (Alaska), lawyer (Great Lakes states). French common name: *lotte*.

ATLANTIC TOMCOD

Microgadus tomcod (Walbaum)



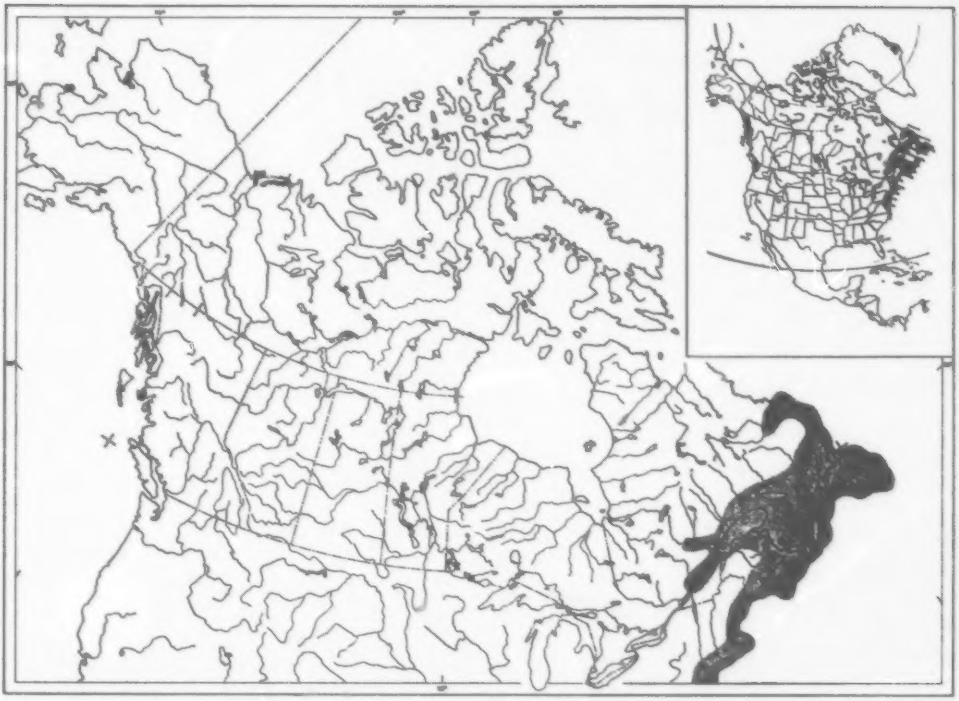
Description Body elongate, length usually 12–13 inches (305–330 mm); robust, not strongly compressed, thickest about origin of first dorsal fin. Head triangular, not markedly depressed, its length 20.1–22.2% of total length; eye moderate, its diameter 14.8–19.7% of head length; snout moderate, its length 33.3–38.5% of head length; interorbital width broad, 29.4–33.3% of head length; maxillary extending to below eye; teeth in jaws and vomer, fine and numerous, somewhat brush-like in both jaws; a slender barbel on underside of lower jaw, its length about equal to eye diameter, about 14–19% of head length. Gill rakers 16–21. Branchiostegal rays 7. Fins: dorsals 3, all more or less rounded; first dorsal in advance of first anal, rays 11–15, second dorsal rays 15–19, third dorsal rays 16–21; caudal rounded; anals 2, inserted below first dorsal and second dorsal, first anal rays 12–21, second anal rays 16–20; pelvic fins thoracic, originating slightly in advance of pectoral fins, the second rays prolonged to almost twice the length of other rays, rays 6; pectorals rounded, inserted just below midpoint of side, rays 16–19. Scales small, somewhat embedded; lateral line white, with slight arch over pectoral fin. Vertebrae 53–57.

Colour The Atlantic tomcod is generally brown or olive-brown with yellow or green tinges on the upper parts, the back is darkest, and the sides paler, and there are indefinite black spots or blotches on the upper part of sides, back, and dorsal fins. The belly is greyish or yellowish white. Anal fins are olive at the margins and all fins are more or less dark mottled.

Distribution A North American marine species, the Atlantic tomcod is distributed in coastal and brackish waters from southern Labrador (Hamilton Inlet–Lake Melville) to Virginia, and is occasionally a permanent resident in fresh water. A related species, *Microgadus proximus*, occurs on the Pacific coast of North America.

Along the Canadian Atlantic coast this species regularly enters fresh or brackish waters. Jeffers (1932) reported it from Pistolet Bay, Nfld., where it is abundant in winter months. In the provinces of Nova Scotia, New Brunswick, and Prince Edward Island it moves into estuarial waters, sometimes ascending streams or rivers well above tidal influence, into fresh water (Scott and Crossman 1959, 1964). In the St. Lawrence it was once abundant in the vicinity of Trois-Rivières and occurred occasionally upstream to Lac St. Pierre, but its numbers have since declined upstream from Trois-Rivières.

In fresh water the Atlantic tomcod has become landlocked in Lake St. John, Que.



(Legendre and Lagueux 1948), and in Deer Lake, Humber River system, Nfld., and is possibly resident in other freshwater areas of coastal Canada.

Biology The tomcod shares with its close relative, the burbot, the characteristic of midwinter spawning, usually beneath an ice cover. The spawning movement pattern is basically the same in all regions in which the tomcod occurs, that is, the ripening adults may spawn in salt water but apparently prefer to move into estuaries and rivers, when available, to spawn over sandy or gravel bottoms in brackish or freshwater shallows. Leim (1924) observed that eggs would hatch in both fresh and saline water, but that the larvae would live only in the latter. However, the existence of entirely landlocked populations, at least in Quebec and Newfoundland, attests to the ability of the species to survive when restricted entirely to fresh water. The area of distribution through the Maritime Provinces and Quebec is rather scattered and it is apparent that spawning does not occur at the same time in all places. Throughout the range along the Atlantic coast spawning possibly occurs from mid-November to about the end of February.

McKenzie (1959), in a discussion of the species in the Miramichi River, N.B., reported that, "The spawning run into the lower freshwater parts of the main branches takes place during the last half of November and early December, with the return movement reaching a peak the last half of January." In Quebec, especially in the vicinity of Trois-Rivières, Vladykov (1955a) reported that active spawning took place from the end of December to the end of January. Details of spawning of Canadian freshwater populations appear to be nonexistent.

The spherical eggs, about 1.5 mm in diameter, are unlike those of the Atlantic cod in that they possess a distinct oil globule, they sink, are adhesive, and readily become attached to the gravel or sand on the bottom. The number deposited depends on the size of the female, but Vladykov reported that a 7-inch (180-mm) fish will deposit 6000 eggs, a 9-inch (230-mm) fish nearly 14,000 eggs, and a 14-inch (355-mm) fish an estimated 65,780 eggs. Schaner and Sherman (1960), in a critical account of fecundity in Massachusetts waters, gave figures of average egg-production for mature tomcod of 20,000 eggs, with a range of 6,000–30,000. The ova they examined showed an average increase in diameter from 0.6 mm in October to 1.4 mm in December. Although we are unaware of reports of actual observation on the spawning grounds, temperatures probably vary between 32° and 39° F (0.0° and 3.9° C) depending on local conditions. Such low temperatures retard incubation but at temperatures of 40° and 43° F (4.4° and 6.1° C) hatching is said to occur in 30 and 24 days, respectively. On hatching, the young are thought to move or drift down river and into the estuaries where the larvae can be caught in the spring. Bigelow and Schroeder (1953) stated that the fry were said to remain through the first summer in the waters where they hatch and grow to a length of 2.5–3.0 inches (65–78 mm) by the following autumn. Although we do not have figures on rate of growth, Vladykov (1955a) reported that three tomcod caught in the St. Lawrence River near Neuville June 19, 1948, measured 1.5–2.0 inches (40–53 mm) in their first year. The following figures on the length–weight relation (modified) are also taken from Vladykov (1955a).

Length		Wt	
(inches)	*(mm)*	*(oz)*	*(g)*
4	101.6	0.2	5.7
6	152.4	1	28
8	203.2	2	56
10	254.0	4	113.4
12	304.8	7	198.5
14	355.6	14	396.9

Accurate figures on maximum sizes have not been reported, but 15 inches (381 mm) in length and 20 ounces (570 g) in weight are usually offered as maximum sizes.

Under normal conditions, excluding landlocked populations, the Atlantic tomcod appears to be an inshore or shallow water marine species that regularly enters fresh or brackish waters during the spawning migration in late fall and winter. It is during the November–February period that it is most vulnerable to exploitation. Studies of movements of Gulf of St. Lawrence populations suggest that many local populations exist, and although some may migrate distances up to 150 miles, others remain in a smaller home territory. Vladykov (1955a) noted that tomcod at Ste. Anne de la Pérade remain throughout their lives in that section of the St. Lawrence River between Rivière Ouelle and Trois-Rivières.

Although it is one of the smallest species in the cod family, the tomcod is as voracious as its larger relatives. Small crustaceans, especially shrimps and amphipods, are its principal food, but it consumes a wide variety of other animals as well, including marine worms, small molluscs, and squid. Fishes are also eaten, especially smelt, sticklebacks, the young of striped bass, alewives, shad, herrings, and sculpins.

The parasite nematode *Porrocaecum* has been identified in the flesh of the tomcod in the Newfoundland area (Templeman et al. 1957), and an acanthocephalan, *Leptorhyncoides thecatus*, was reported by Pigeon and Vallée (1937) in the digestive tract of tomcod from the St. Lawrence River.

Much of the available information relating to spawning and early life history of tomcod was gathered many years ago for waters of the Gulf of Maine and southward, and hence should be applied with caution to Canadian populations, especially those of the Gulf of St. Lawrence region, which seem to be the most utilized. Despite the fact that tomcod are angled from Labrador to Ste. Anne de la Pérade and also support a small but worthwhile fishery of about one million pounds, details on rates of growth and other biological aspects seem not to be available.

Relation to man The Atlantic tomcod is sought, both as a sport fish and a commercial fish, in various parts of eastern Canada. The tasty white flesh and the readiness of the species to take a baited hook during its winter spawning aggregations formed under the ice in late December and January, combine to make tomcod fishing a popular winter activity in various parts of the country, particularly in Quebec and New Brunswick. The winter fishery in the Trois-Rivières–Ste. Anne de la Pérade region of the St. Lawrence River has been vividly described by Vladykov (1955a) who noted that night fishing was best and that 500–600 tomcod could be caught by one person between 7:00 PM and 7:00 AM. This fishery has been seriously affected by pollution, especially in the vicinity of Trois-Rivières, where catches have been drastically reduced.

In New Brunswick the principal fishery is in the lower Miramichi River and is largely a bagnet fishery conducted in the late November–January period between Loggieville and Newcastle. This catch is processed mainly for animal food.

In the inshore waters of the Northwest Atlantic a commercial catch of 240 metric tons was reported for 1967.

Wherever the Atlantic tomcod occurs in sufficient numbers it may become the object of a small fishery but few such fisheries are documented. The tomcod is particularly susceptible to various types of industrial wastes, produced particularly by pulp and paper mills, many of which discharge accumulated wastes into rivers after the ice cover is formed. Such discharges are less conspicuous and their deleterious effects often go unnoticed. Tomcod, however, spawn only after the ice cover is formed. Their eggs and larvae are extremely sensitive and quickly succumb in the presence of chemical pollution and low oxygen levels created by industrial waste discharge. Whereas some other fish species may be able to move out of the region, to return when pollution ceases, the tomcod is unable to reproduce and soon disappears entirely from the affected region.

Nomenclature

Gadus tomcod — Walbaum 1792: 133 (type locality Long Island, after Schöpf)
Gadus frost — Walbaum 1792: 134
Morrhua pruinosa — Perley 1852: 211
Gadus pruinosus Mitchill — Adams 1873: 305
Gadus tomcod (Walbaum) — Cox 1893: 38
Microgadus tomcod (Walbaum) — Bailey et al. 1960: 22

Etymology *Microgadus* — small; Latin name, akin to English word cod; *tomcod* — a vernacular name.

Common names Atlantic tomcod, tomcod, winter cod, frostfish, tommy cod, snig, tommycod, petite morue, loche, poisson des chenaux. French common name: *poulamon atlantique*.

Suggested Reading — Gadidae

BIGELOW, H. B., and W. C. SCHROEDER. 1953. Fishes of the Gulf of Maine. U.S. Fish Wildl. Serv. Fish. Bull. 74, vol. 53: 577 p.

CLEMENS, H. P. 1951a. The food of the burbot, *Lota lota maculosa* (LeSueur), in Lake Erie. Trans. Amer. Fish. Soc. 80: 56–66.

1951b. The growth of the burbot, *Lota lota maculosa* (LeSueur), in Lake Erie. Trans. Amer. Fish. Soc. 80: 163–173.

Fish, M. P. 1930. Contributions to the natural history of the burbot, *Lota maculosa* (LeSueur). Bull. Buffalo Soc. Natur. Sci. 14(3): 1–20.

Hopkins, E., and C. M. Ritchie. 1943. The burbot. U.S. Fish Wildl. Serv. Fish. Leafl. 21: 6 p.

Lawler, G. H. 1963. The biology and taxonomy of the burbot, *Lota lota*, in Heming Lake, Manitoba. J. Fish. Res. Bd. Canada 20: 417–433.

Lindsey, C. C. 1956. Distribution and taxonomy of fishes in the Mackenzie drainage of British Columbia. J. Fish. Res. Bd. Canada 13: 759–789.

McCrimmon, H. R., and O. E. Devitt. 1954. Winter studies on the burbot, *Lota lota lacustris*, of Lake Simcoe, Ontario. Can. Fish Cult. 16: 34–41.

Robins, C. R., and E. E. Deubler, Jr. 1955. The life history and systematic status of the burbot, *Lota lota lacustris* (Walbaum), in the Susquehanna River system. N.Y. State Mus. Sci. Serv. Circ. 39: 1–49.

Svetovidov, A. N. 1962. Gadiformes (Eng. ed.). Fauna of the USSR 9(4), Fishes. Zool. Inst. Acad. Sci. USSR, n.s. 34(1948): 1–304. (Transl. publ. by Nat. Sci. Found., Washington, D.C.).

Vladykov, V. D. 1955. Fishes of Quebec. Cods. Dep. Fish. Que. Album 4: 12 p.

THE SILVERSIDES AND FLYINGFISHES — Order Atheriniformes

Virtually the only way to describe or delineate this order, as presently organized, would be to list the distinctive characteristics of each of the diverse suborders, Atherinoidei, Exocoetoidei, and those of some of the many families contained in them. The complexity of the group is obvious when we consider that the present arrangement includes fishes that, in the past, were placed in such groups as Synentognathi, Beloniformes, Cyprinodontiformes, Percesoces, Mugiliformes, Phallostethiformes, and Perciformes (Greenwood et al. 1966). However, the Cyprinodontiformes are treated as a separate order here p. 630.

By means of extensive and penetrating anatomical and morphological studies Rosen (1964) was able to demonstrate that the halfbeaks, the silversides, and those forms related to each, should be more closely aligned with the killifishes than with the mullets and barracudas, as they were prior to the study. He suggested, on the basis of similarities shown by these superficially diverse forms, that the families probably had "a common (Eocene) ancestry in fresh and brackish waters of Australia and from this region they subsequently spread around the world into virtually all of the tropical temperate, marine, and freshwater environments."

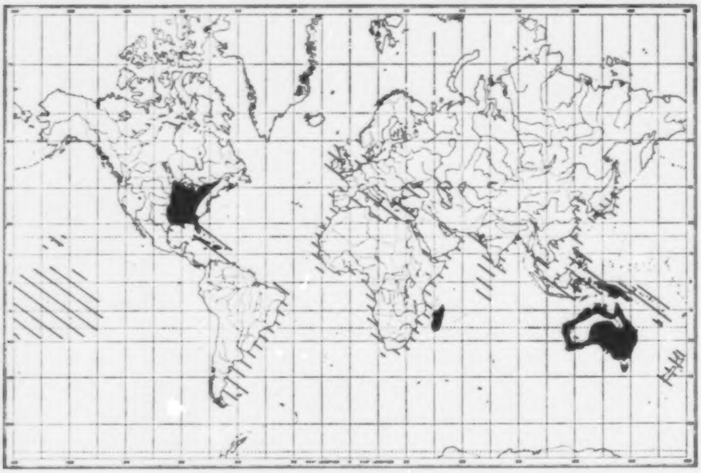
For this discussion we are concerned with only a single silverside, family Atherinidae.

SILVERSIDES FAMILY — Atherinidae

Usually small, silvery, somewhat translucent fish with a pronounced lateral stripe. They are laterally compressed, fusiform; the head is scaled, the mouth is terminal with the appearance of being directed upward, and the eyes are large. Teeth are usually present on the jaws, often on the palatines and vomer. The superior pharyngeals are united and bear teeth. There are 2 well-separated dorsal fins, the first smaller, inconspicuous with 3–8 spines. The pectoral fins are high on the body; and the pelvic fins, of 1 spine and 5 rays, are abdominal. The anal fin, which has a weak spine, is short or long, square or falcate; and the caudal fin is forked. The lateral line is absent or restricted to a few tubes; the scales are cycloid. There are no pyloric caeca; the swim bladder is present and physoclistous.

Although the majority are 2–6 inches long and from tropical surface and shore waters, some temperate New World forms reach 1–2 feet. They are distributed around the world between 50°N and 50°S, in salt, brackish, and fresh water, including lakes and mountain torrents.

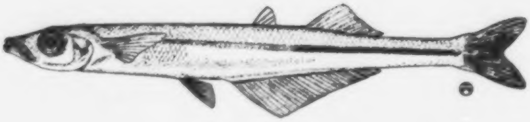
There are 50 genera and about 160–170 species, and silversides are known from the lower Eocene to Recent.



World Distribution of the Silversides

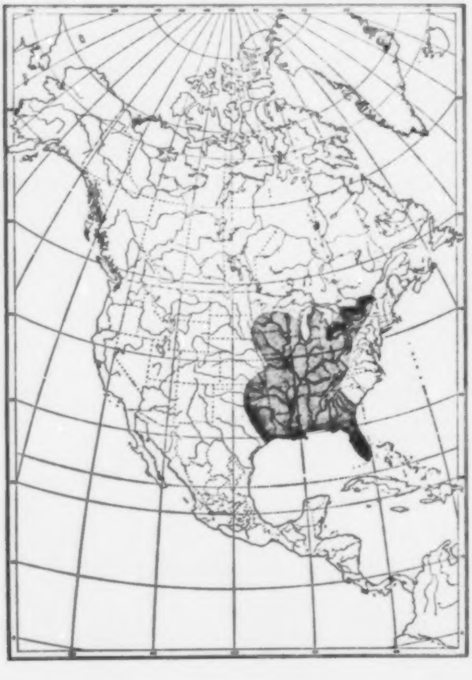
BROOK SILVERSIDE

Labidesthes sicculus (Cope)



Description A slender, translucent, pikelike fish; body slender, elongate, average length usually 3 inches (76 mm), only slightly compressed laterally, deepest in front of first dorsal fin. Head somewhat long, distinctly flattened above, 17.8–19.7% of total length; eye diameter 27.3–34.8% of head length; interorbital wide, 27.3–34.8% of head length; snout long, pointed, jaws nearly equal, or lower jaw projecting slightly; mouth relatively large, somewhat beaklike, gape terminating in advance of eye; teeth long, sharp, conical, slightly recurved, in 3 rows on jaws. Gill rakers long and slender, 24–29 (Indiana). Branchiostegal rays 6, aciniform. Fins: dorsals 2, first spiny, second soft rayed, first dorsal of 4 spines, second dorsal of 1 spine and 10 or 11 branched rays; caudal distinctly forked; anal fin of 1 spine and 23–27 branched rays; pelvic fins abdominal, of 1 spine and 5 rays; pectoral fins well developed, tips reaching almost to origin of pelvics, pointed, inserted about midlaterally, behind head, of 12 or 13 rays. Scales small, cycloid, in lateral series about 95; lateral line incomplete, often only a few pores. No pyloric caeca. Vertebrae 40–43.

Colour Overall colouration of the brook silverside is pale green, sometimes olive; the body is rather transparent and the swim bladder and vertebral column can often be seen through the muscle, particularly in small fish 1.5—2.0 inches (38–51 mm) long. Scales on back usually outlined with fine dark spots. There is a brilliant silvery lateral band along the sides.



Distribution The brook silverside is widely distributed throughout the fresh waters of central North America. In the United States it is found in lakes and streams in the Mohawk River system of New York (presumably a canal immigrant), the Alleghany River system, west to the lower peninsula of Michigan, through Wisconsin and Minnesota, and thence south to the Gulf states, Texas, and Oklahoma.

In Canada it occurs in the drainages of the upper St. Lawrence River, the lower Ottawa River, and in lakes Ontario, Erie, and St. Clair, in Georgian Bay and in some tributary streams. This species appears to be restricted mainly to clear, weeded lakes.

Biology Canadian populations of brook silversides, which are confined to a small region in south-central Canada, have received scant attention except for the observations by Bensley (1915), and Keast and Webb (1966). Consequently much of the following information has been obtained from observations of the species made in waters of the northern United States.

Spawning occurs in spring and early summer. In southeastern Michigan Hubbs (1921a) observed that spawning commenced in May and extended into July in 1920. In a marl lake in northern Indiana, Nelson (1968b) noted that spawning extended from June 17 to August 5 in 1966. Spawning takes place in and around aquatic vegetation, especially *Scirpus* and *Potamogeton,* but apparently may also occur over gravel in a moderate current. Possibly the large numbers reported by Bensley in the flowing water near the falls of the Go Home River, Georgian Bay, Lake Huron, Ont., were engaged in spawning. The eggs are orange in colour, 0.8–1.2 mm in diameter, with numerous oil globules, and each egg has a long filament whose length is many times the diameter of the egg. This filament is adhesive, although the egg is not, and functions as an anchoring device for the egg.

Growth of young silversides is extremely rapid. Nelson (1968b) noted that the rate at which maximum size is attained exceeds that of all but one species in the list of species presented by Beverton and Holt (1959) in their discussion on aging of fishes. It lives for 1½ years only, rarely completing 2 years. The young hatch, grow to their maximum size the same year, overwinter, spawn the following spring and summer, and die. Nelson noted that in an Indiana lake population, some fish reached the modal size of the 12-month-old spawning group of their own year-class in only 3 months. Nelson presented a comprehensive discussion of the growth characteristics of this Indiana population. The observed maximum total length of Ontario specimens is 3.5 inches (89 mm), but most adults average about 3 inches (76 mm) in their second year.

The brook silverside is adapted for living in the surface layers. On hatching, the young move offshore over deep water but remain in the upper layers, usually with their flattened head in contact with the surface film. The young remain offshore, apparently as a result of a negative response to large objects or bodies. Hubbs (1921a) suggested that this characteristic functions as a predator-avoidance mechanism, keeping the vulnerable young out of contact with such predatory groups as centrarchids and percids. They form large schools during daylight hours but tend to disperse at night. As they increase in size the aversion to large bodies declines and they move in over shoals, usually in August and September.

In Ohio it has been noted that the species tended to disappear from waters that became turbid, which is a condition that has become more widespread in southern Ontario as a result of construction and agricultural activities. We have few observations to indicate that the brook silverside attains an abundance comparable to that in lakes of the northern United States, where, for example, at least 11,500 specimens were used in Nelson's study in Indiana. But in Crippen Lake, Leeds County, in eastern Ontario, Toner (1943) noted that immense numbers could be caught by seine at night, but not in daytime. Toner also noted that large numbers were occasionally observed from the dock at Kingston, Ont.

The predaceous food habits of this delicate little fish have been reported by Bensley (1915) and more recently by Keast and Webb (1966). The latter noted that it is a specialized feeder, consuming Cladocera (often to 80% by volume), small flying insects (to 40%), and *Chaoborus* (phantom midge) larvae (to 50%). The smaller the fish the larger the amount of Cladocera eaten. Bensley's observations of Georgian Bay specimens, although more general, are in agreement.

It feeds in a snapping fashion, for which its beaklike, toothed jaws are ideally suited. Numerous authors noted that it may frequently leap out of the water to catch flying insects.

Parasites of brook silversides from Lake Erie have been recorded by Bangham and Hunter (1939) who noted that specimens from eastern Lake Erie were relatively unaffected although those from the west end of the lake harboured cestodes, trematodes, and nematodes.

Relation to man The brook silverside is an ideal forage fish and when abundant it may be an important prey for game fishes. It is undoubtedly of very minor importance in most Canadian waters because of its low numbers and limited distribution. Larger specimens are occasionally used for bait by sports fishermen.

Nomenclature

Chirostoma sicculum	— Cope 1865: 81 (type locality Grosse Isle, Detroit River)
Labidesthes sicculus	— Cope 1870: 455

Etymology *Labidesthes* — a pair of forceps; to eat; *sicculus, siccus* — dried; found in half-dry pools.

Common names Brook silverside, skipjack, silverside, brook silversides, brook-silverside. French common name: *crayon d'argent.*

Suggested Reading — Atherinidae

BENSLEY, B. A. 1915. Fishes of Georgian Bay. Contrib. Can. Biol. Sess. Pap. 39b(1911–14). p. 1–51.

CAHN, A. R. 1927. An ecological study of southern Wisconsin fishes. Ill. Biol. Monogr. 11(1): 1–151.

HUBBS, C. L. 1921. An ecological study of the life-history of the fresh-water atherine fish *Labidesthes sicculus*. Ecology 2: 262–276.

NELSON, J. S. 1968. Life history of the brook silverside, *Labidesthes sicculus*, in Crooked Lake, Indiana. Trans. Amer. Fish. Soc. 97: 293–296.

THE STICKLEBACKS AND RELATIVES —

Order Gasterosteiformes (Thoracostei)

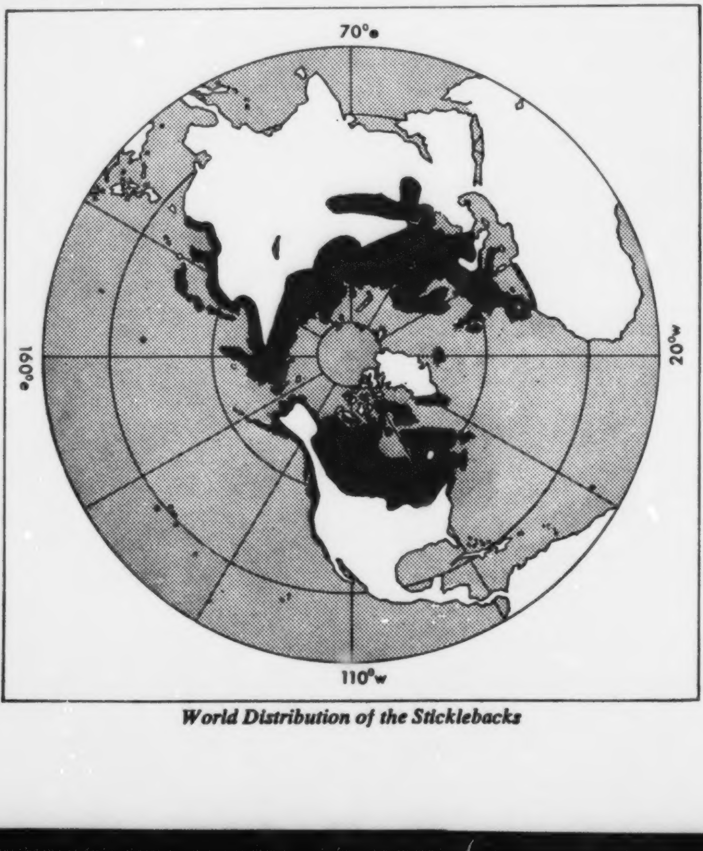
This order includes the sticklebacks, tube-snouts, pipefishes, seahorses, and snipefishes, a mixed group of spiny-rayed, principally warmwater, marine fishes. Members of the order are without a duct to the swim bladder; fin spines may be present or not; the pelvic fin when present is abdominal or thoracic and may possess a stout spine; pelvic bones are not attached to cleithra. Branchiostegal rays 1–5.

As herein defined the order includes about 50 genera and approximately 200 species.

STICKLEBACK FAMILY — Gasterosteidae

The sticklebacks are small, laterally compressed fishes with slender caudal peduncles; the head is moderate, the skull elongate; the mouth is small, the teeth also small, but well developed; upper jaw bordered by premaxillary, the maxillary being slender and articulating anteriorally with the premaxilla. Branchiostegal rays 3. The well-developed dorsal and pelvic fin spines are characteristic of the group; the soft dorsal fin is preceded by 3–16 isolated, well-developed spines, each with a triangular membrane; usually a short spine is closely associated with a soft dorsal fin of 6–14 rays; the caudal fin is rounded to slightly forked, with 12 soft rays; anal fin, usually about as long as soft dorsal, of 6–12 rays, preceded by a short but strong spine; pelvic fins thoracic in position, usually posterior to pectoral fin base, of a single, strong well-developed spine and 0–3 soft rays; pelvic bones not attached to cleithra; pectoral fins somewhat fanlike, inserted laterally, and with base in a vertical line, of 10–12 rays. Physoclists. Vertebrae 27–42.

The members of the family occur in shallow, inshore areas of marine and fresh waters of North America, northern and central Asia, Europe, and Algeria.



World Distribution of the Sticklebacks

KEY TO SPECIES

1 Dorsal spines usually 9 (7–12), short and inclined alternately to left and right; gill membranes united, but entirely free from isthmus; no distinct bony plates on sides .... NINESPINE STICKLEBACK, *Pungitius pungitius* (p. 671)

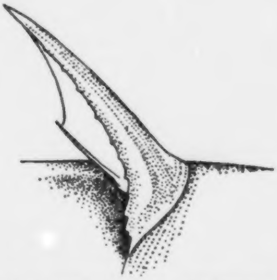
Dorsal spines 3–6; gill membranes united to isthmus (membranes united but free from isthmus in *Culaea*); lateral bony plates present or absent 2

2 Dorsal spines 4, 5, or 6, spines may be long or short; no distinct bony plates on sides; pelvic skeleton without large, wide, median posterior processes 3

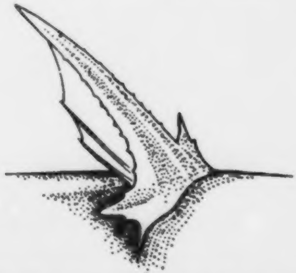
Dorsal spines 3 (rarely 2 or 4), usually with distinct vertical bony plates along sides; pelvic skeleton with large, wide, median posterior processes 4

3 Dorsal spines 4, 5, or 6, short; pelvic spines also short; length of all spines usually less than eye diameter; pelvic skeleton, if present, with narrow median posterior processes .... BROOK STICKLEBACK, *Culaea inconstans* (p. 661)

Dorsal spines 4 (rarely 5), of varying lengths and long, inclined alternately to left and right; length of first and second dorsal spines and pelvic spines distinctly greater than eye diameter; pelvic skeleton with lateral posterior processes .... FOURSPINE STICKLEBACK, *Apeltes quadracus* (p. 658)



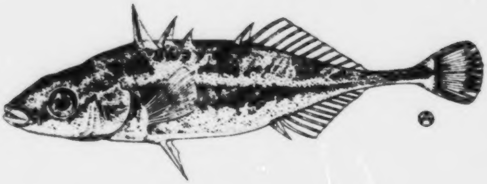
4 Pelvic fin of 1 spine and 1 soft ray, spine with 1 pointed cusp at base; caudal peduncle usually with a keel; body without round black spots; colour in life green, blue or silvery .... THREESPINE STICKLEBACK, *Gasterosteus aculeatus* (p. 665)



Pelvic fin of 1 spine and 2 soft rays, spine with 2 well-developed pointed cusps at base; caudal peduncle keelless; many round black spots along sides; colour in life lemon-yellow .... BLACKSPOTTED STICKLEBACK, *Gasterosteus wheatlandi* (p. 669)

FOURSPINE STICKLEBACK

Apeltes quadracus (Mitchill)



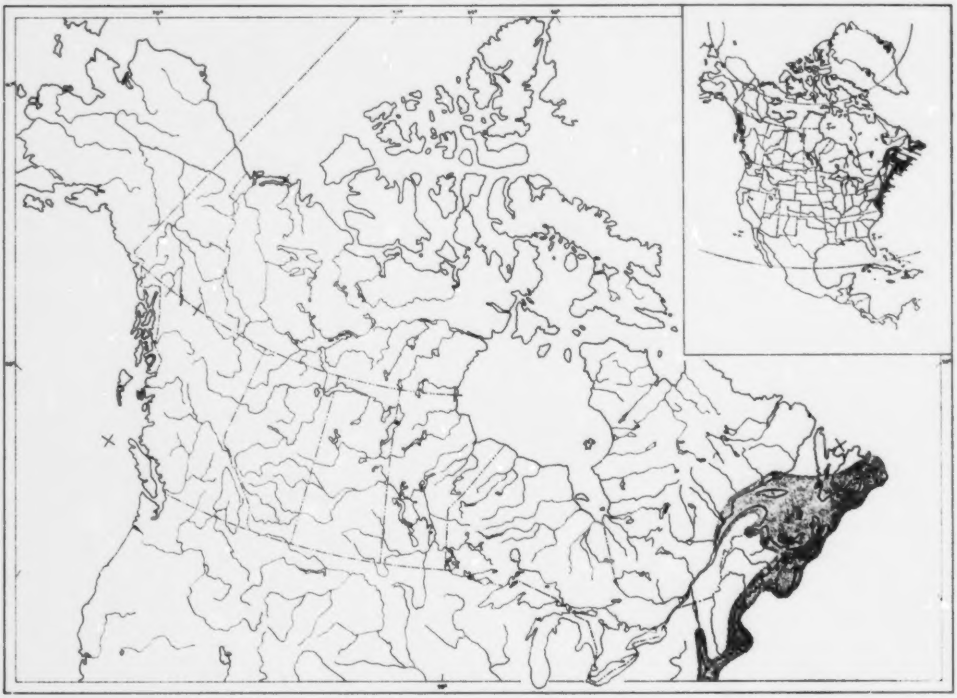
Description Body moderately elongate, somewhat compressed laterally, length 2.0–2.5 inches (51–64 mm), greatest depth in front of the soft-rayed dorsal fin, body depth 16.2–20.0% of total length; in cross section body somewhat triangular; caudal peduncle slender and without a keel. Head compressed, pointed, 22.2–26.3% of total length; eye diameter 25.0–33.3% head length; mouth terminal, small; lower jaw projecting slightly; single series of slender teeth in each jaw. Gill membranes broadly united to isthmus. Branchiostegal rays 3. Fins: dorsal of 3 or 4 isolated spines, inclined to left or right, first and second spines about equal, about 33.3% length of head, third and fourth about one-half length of first, followed by 10–13 soft rays that are preceded by 1 spine attached to the anterior edge of soft dorsal rays; soft dorsal origin about midpoint of body slightly in advance of anus; caudal truncate, rounded corners; anal of 1 spine and 7–10 soft rays, the spine equalling spine on soft dorsal, attached by membrane to anterior edge of fin, fin terminating under posterior end of soft dorsal; pelvics with 1 spine and 2 slender, soft rays, spine heavy, lightly serrated, about one-half length of head; pectorals inserted on sides short distance behind gill opening, one-half length of head, moderate, rounded, rays usually 11, rarely 12. Skin naked, without scales or bony plates; a ridge on each side of lower abdomen behind pelvic fins due to separate posterior processes, no united median posterior processes between pelvic fins; lateral line present, not obvious. Vertebrae 29–33.

Colour Adults olive-green to brownish olive above, with dark mottlings on sides; lower sides and belly silvery; males may be almost black. Pelvic spine and membrane red on ripe males at spawning time. General colour of body of newly hatched larvae dark brown.

Systematic notes In a review of the species throughout its relatively small range, Krueger (1961) concluded that vertebral numbers tended to decrease from north to south, but that dorsal and anal rays and dorsal spines varied irregularly, although dorsal spines appeared to be correlated with salinity.

Distribution The fourspine stickleback is generally confined to coastal areas of eastern North America, from the Gulf of St. Lawrence south to Virginia. Typically a marine species, it rarely inhabits fresh water and commonly inhabits brackish, estuarial waters.

In Canada it is present in estuarial environments in southern Newfoundland (where it probably reaches its northern limit of range in western Newfoundland and nearby eastern Quebec), Prince Edward Island, Nova Scotia, New Brunswick, and the Gulf of St. Lawrence shore region of Quebec. An exception to the typical habitat exists in Nova Scotia where the fourspine stickleback is well established in a number of lakes and streams, far removed from the sea.



Biology The fourspine stickleback spawns in spring or early summer (May–July). Males and females appear on the spawning grounds where they separate, and the males, alone in shallow drainage channels, begin to construct the nests. The nest is made up of aquatic plants and twigs, bound together in an intricate manner to resemble a cup-shaped basket, by a threadlike material from kidney secretion (Breder 1936a). The secretion hardens into a tough thread on contact with water. When the nest is partially completed, the male approaches the female and performs a mating dance, swimming in extremely fast circling movements around, or in front of, her. At intervals he stops and displays both red pelvic spines. Eventually the female is lured onto the partially completed nest where she is induced to spawn (Reisman 1963).

The amber-coloured eggs, each about 1.5 mm in diameter, are deposited in the shallow nest in clusters of about 40 and adhere to each other. If by chance the eggs miss the nest the male will pick up the egg mass and place it in the nest. The eggs are liberally fertilized and then covered completely by the construction of an inverted nest or roof. The female is always driven off. The male leaves a hole on each side of the nest just large enough for him to insert his snout to aerate the eggs. By putting his snout into the hole and expelling water from the gill chamber, he draws water into the nest through the hole on the opposite side. He may then construct another nest on top of the first one. The increasing responsibility of the male, which includes aerating nests, building additional nests, chasing away enemies, and occasionally eating, keeps him extremely active. The male is known to build as many as four successive nests, one on top of another. The eggs and young are guarded by the male whose zealous adherence to duty evoked the following from Seal (1932): "There is probably no form of animal life more fiercely devoted to the protection of its progeny. The eggs are aerated by drawing water through the orifices in the nest at intervals of not over a minute. In the intervals he scouts the neighbourhood of the nest looking for enemies and devouring such acceptable food as he encounters."

Newly hatched larvae are 4.2–4.5 mm in length. Growth is rapid and when 3 days old they have grown to a length of 6.2–6.5 mm. At 8 days they are approximately 7 mm long (Kuntz and Radcliffe 1917). Male fish 24.0–41.4 mm in total length, have a one-calendar-year life span (Schwartz 1965). Some females can live through a second winter to spawn the following season.

As noted above, the fourspine stickleback is usually found in salt or brackish waters but does occur in fresh water occasionally.

In eastern Canada food of this stickleback consists mainly of planktonic plants and animals.

There are few published records of parasites infecting this species, but *see* Hanek and Threlfall (1970) for helminth parasites.

Relation to man The fourspine stickleback can be used as bait in areas where it is abundant. Schwartz (1965) suggested this species might be useful as an experimental animal because of its rapid growth and relatively short life span.

Nomenclature

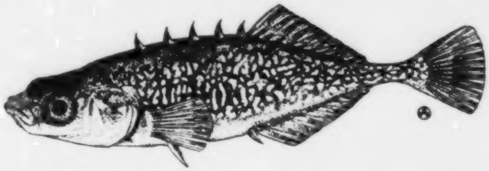
Gasterosteus quadracus — Mitchill 1815b: 424 (type locality New York)
Gasterosteus millepunctatus Ayres — Bean 1903b: 342
Apeltes quadracus Goode and Bean — Bean 1903b: 342
Apeltes quadracus Mitchill — Halkett 1913: 73
Gasterosteus quadracus Mitchill — Jordan, Evermann, and Clark 1930: 239
Gasterosteus apeltes Cuvier and Valenciennes — Jordan, Evermann, and Clark 1930: 239

Etymology *Apeltes* — privative, shield; *quadracus* — four spine.

Common names Fourspine stickleback, stickleback, pinfish, mud-pouch, mud-perch, bloody stickleback. French common name: *épinoche à quatre épines*.

BROOK STICKLEBACK

Culaea inconstans (Kirtland)



Description Body deep and compressed laterally, length about 2 inches (51 mm), tapering to a moderately slender caudal peduncle, also compressed laterally, and keelless, body depth 14.9–23.5% of total length. Head regularly conical, obliquely truncated by the lower jaw, head length 23.1–29.0% of total length; eye large, diameter 21.4–37.5% of head length; teeth on jaws small, well developed. Gill membranes united but free from isthmus. Branchiostegal rays 3. Fins: dorsal of 5 (range 4–7) short, isolated spines with backward curve, free from each other and each with individual membrane, and with a cartilagineous ridge along base of fin, spines depressible in a groove, followed by 9 or 10 (rarely 8, 11, or 12) soft dorsal rays; caudal rounded, 12 rays; anal of 1 short spine, situated directly beneath last dorsal spine, followed by 9–11 (rarely 12) soft rays, originating slightly behind origin of soft dorsal; pelvic 1 strong, spine and 1 ray (pelvic skeleton absent in some populations); pectorals of 9–11 soft rays, large, almost one-half length of head. Body smooth, scaleless, but with minute bony plates about lateral line pores. Vertebrae 29–35.

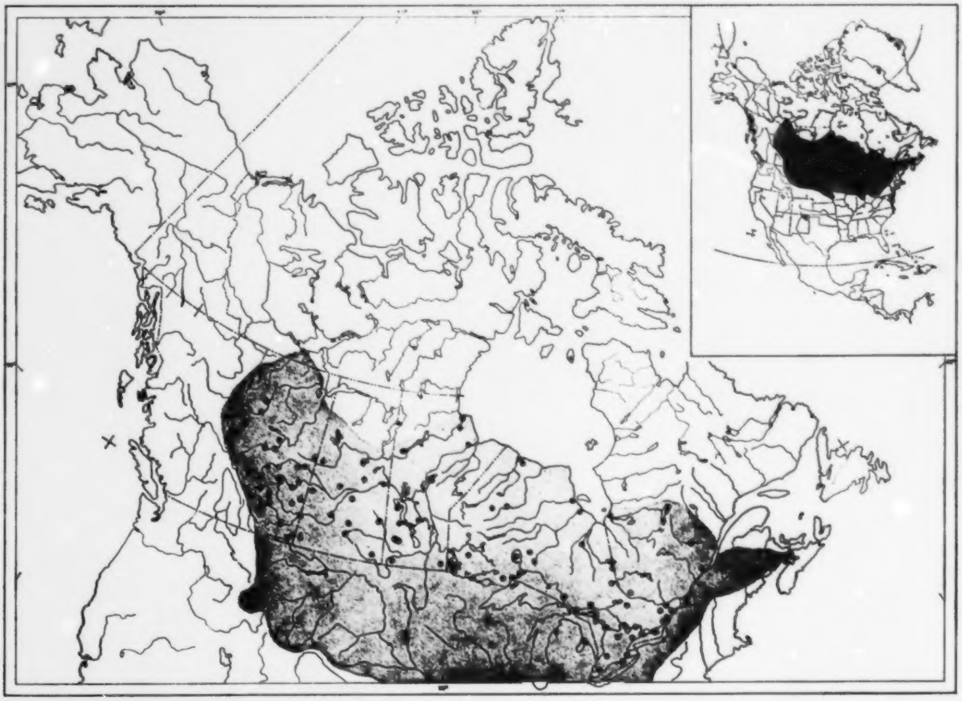
Colour Overall colour of adults olive-green to dark, soft, olivaceous black of spawning males, with numerous light spots on sides, on some individuals replaced by light, wavy, vertical lines. During spawning season, body and fins of males may be jet black, sometimes tinged with copper; females usually dusky. Males may have faint reddish tinge on pelvic membranes.

Systematic notes The brook stickleback was known for many years by the name *Eucalia inconstans*. Whitley (1950) noted that the genus *Eucalia* was preoccupied in entomology and proposed the genus *Culaea*, a name that is slowly becoming established since brought to North American notice by Bailey and Allum (1962).

Nelson (1969) noted that dorsal and pelvic spine lengths on this stickleback exhibit clinal variation, and are longest in Wisconsin, decreasing in length from this centre. In some Alberta and Saskatchewan localities, the entire pelvic skeleton is absent in a high proportion of the individuals (Nelson and Atton 1971).

Distribution The brook stickleback ranges widely in cool, clear waters through north-central North America; from Nova Scotia and Maine on the east, through New York, Pennsylvania and west through Iowa, but not Kansas (Cross 1967: 328), to Montana; north to the Hudson Bay drainage and the southern Northwest Territories. Relict populations are known to occur outside this range, such as in New Mexico (*see* Nelson 1969).

In Canada, it occurs from Nova Scotia and New Brunswick west, barely entering



British Columbia, and north to the Hudson and James Bay drainages of Quebec, Ontario, and Manitoba, and the Hay River region of Great Slave Lake.

Biology The brook stickleback spawns in shallow water from late April to July, depending upon the water temperature. Laboratory experiments reported by Winn (1960) suggested that spawning is inhibited if the temperature of the water is above 66.2° F (19° C). In southern Minnesota, where this species spawns from late April or early May to the middle of June, Jacobs (1948) stated that the water must attain a minimum temperature of 46.4° F (8° C) before spawning begins. Spawning is reported to occur later in more northerly latitudes (Winn 1960). On July 1, 1929, in Little Wonder Pond, a spring-fed pond in southwestern Ontario, Harkness and Ricker (1929) found nests and eggs of sticklebacks, presumably this species.

Winn (1960) and Thomas (1962) gave good accounts of the spawning and behavioural activities of this species. The males arrive first in the shallow water, establish territories, and begin nest construction. A male may construct two successful nests in one season. The nest is built on stems of reeds or grass close to, and sometimes on, the bottom. Dead grass and fine fibres are used in the early nests, but as the season advances, green algae is used. These fragments are bound together with a kidney secretion, as with other members of the stickleback family. The nest is more or less round in shape, about three-quarters of an inch in diameter, with a single opening. A second opening is made when the female, on depositing her eggs, leaves the nest. Repair of this second opening is attempted by the male. As eggs are added (from more than one female), the nest size is increased by the male. Some males attain a jet black breeding colour prior to nest building, others after completion of the nest. Female sticklebacks also change colour when ready to spawn from uniform pale green to a variegated, dark and light pattern.

The male entices the female into the nest by a series of nips, butts, and nudges. By prodding her ventral and caudal peduncle areas after she has entered the nest, he induces the deposition of eggs, each nearly 1 mm in diameter, transparent, light yellow, demersal, and adhesive. She is then driven off, the eggs are fertilized and cared for by the male. At the entrance, the male fans with his pectoral fins, increasing this activity as the eggs develop. Hatching takes place in 8–9 days at 65° F (18.3° C) (Breder and Rosen 1966). The male defends his territory against intruders of his own size, or slightly larger, until the young swim away from the remains of the nest.

Indications are that the brook stickleback grows rapidly, and attains sexual maturity in 1 year. Maximum size is 3.5 inches (87 mm).

This stickleback inhabits the clear, cold, densely vegetated waters of small streams and spring-fed ponds, and is found along the swampy margins of beach ponds of larger lakes. Salinity tolerance experiments were reported by Nelson (1968a) and indicated that brook sticklebacks had considerable tolerance to salt water, at least for short periods, and continued to feed in salinities of 50% sea water (17.5‰) but ceased all activity at 70%. Nelson also noted that tolerance was greater at 46.4° F (8° C) than at 60.8° F (16° C). Natural occurrence in salt or brackish water is unusual, but Cox (1922), reporting on such a case in a discussion of the Hudson Bay collections of 1920, quoted Johansen regarding a collection from a "brackish land-locked pool." Miller and Thomas (1957) reported that it inhabits the alkaline lakes ("potholes") in the prairies of Alberta. It is found occasionally in well-protected coves and bays of large lakes, and in sluggish, stagnant water, and has been caught by trawl in Lake Huron at all depths to 30 fathoms. The apparent preference of the brook stickleback for cool water limits distribution southward, and it is usually found only in cooler waters at the southern limits of the range.

Migratory movements for such small species are not spectacular and are not well documented but Lamsa (1963) reported downstream movements of brook sticklebacks involving large numbers of individuals. In 1 week, June 8–14, 1958, 2851 specimens were trapped in a downstream trap in Silver Creek, which flows into Georgian Bay, Lake Huron, Ont. From June 28 to July 4, 1959, 908 were caught in the same stream. The mean water temperature was 66.2° F (19° C) during this week. The cause of the movement is unknown but the activity was concentrated during the 1 week of each year.

This species is mainly carnivorous, its food consisting of the larvae of a wide variety of aquatic insects and crustaceans, and also the eggs and larvae of other fishes (sometimes of its own species), as well as snails, oligochaetes, and algae. Dymond (1926) reported its food in Lake Nipigon consisted of midge and caddisfly larvae and ostracods.

The brook stickleback is preyed upon by many species of fishes but probably as an incidental or occasional item rather than a regular one. Ricker (1932) noted that it was eaten occasionally by brook trout in hard-water streams and ponds. It may be an important item in the diet of smallmouth bass and also is eaten occasionally by northern pike. It undoubtedly falls prey to fish-eating birds, such as kingfishers, herons, and mergansers.

Parasites of the brook stickleback are many and varied. Studies were published by Bangham and Hunter (1939) for Lake Erie, Bangham and Venard (1946) for Algonquin Park, Bangham and Adams (1954) for British Columbia, and Bangham (1955) for Lake Huron. The trematode *Bunoderina eucaliae* was a common parasite in fish from all areas except Algonquin Park, where none of the seven fish examined contained parasites of any kind. Lawler and Watson (1958) found the cestode *Schistocephalus solidus* in the brook stickleback in Heming Lake, Man., and Paetz and Nelson (1970) noted that *Schistocephalus* may account for more than one third of an infected fish's weight in Alberta. Hoffman (1967), in a review of parasites of the species in North American waters, listed two protozoans, nine trematodes, five cestodes, four nematodes, four acanthocephalans, one leech, one mollusc, and one crustacean.

Relation to man The brook stickleback, although occasionally used for bait, is not of direct commercial importance. Dawson (1859), in an account of the species in the vicinity of Montreal, noted "it is easily taken with a dipnet, and great numbers are captured by young anglers for bait." Nor is it a forage fish of significance, except perhaps in lakes on the Precambrian Shield that lack other forage fishes. It is an interesting aquarium species and could be used in laboratory studies of behaviour, but a supply of live food, such as the brine shrimp *Artemia,* is desirable. Frozen brine shrimp may also be used. Like most sticklebacks, it is a pugnacious little creature and will harass, and eventually kill, other small fishes kept with it.

Nomenclature

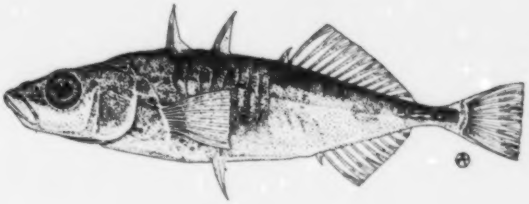
Gasterosteus inconstans	— Kirtland 1841a: 273 (type locality Trumbull Co., Ohio)
Gasterosteus gymnetes	— Dawson 1859: 321
Gasterosteus inconstans Kirtland	— Cox 1896b: 68
Eucalia inconstans pygmaea (Agassiz)	— Jordan and Evermann 1896–1900: 744
Gasterosteus globiceps Sauvage	— Jordan and Evermann 1896–1900: 744
Eucalia inconstans Kirtland	— Evermann and Goldsborough 1907a: 106
Gasterosteus pygmaeus Agassiz	— Halkett 1913: 72
Eucalia inconstans (Kirtland)	— Forbes and Richardson 1920: 222
Eucalia pygmaea (Agassiz)	— Jordan, Evermann, and Clark 1930: 238
Culaea, nov.	— Whitley 1950: 44
Culaea inconstans	— Bailey and Allum 1962: 93

Etymology *Culaea* — a coined name; *inconstans* — meaning variable.

Common names Brook stickleback, five-spined stickleback, variable stickleback, common freshwater stickleback, common stickleback, pinfish, six-spined stickleback. French common name: *épinoche à cinq épines.*

THREESPINE STICKLEBACK

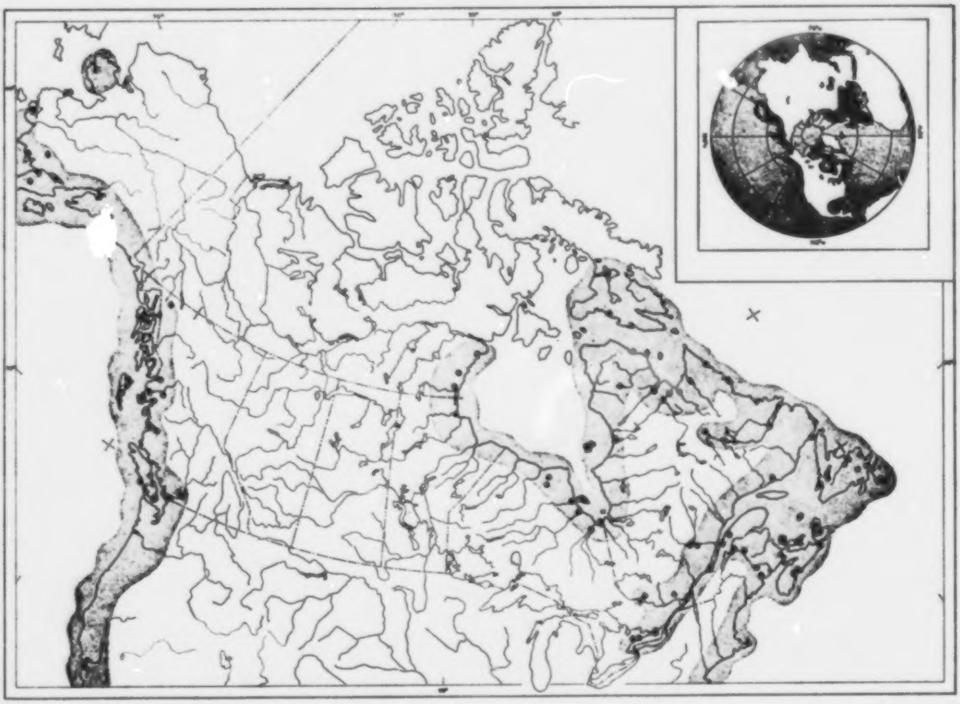
Gasterosteus aculeatus Linnaeus



Description Body compressed laterally, elongate, average length 2 inches (51 mm), tapering to a slender, depressed caudal peduncle that is usually keeled in marine forms, body depth 20–22% of total length. Head 23.8–26.3% of total length, pointed; eye diameter 25% of head length; teeth on jaws slender, sharp. Gill covers finely striated. Gill membranes broadly joined to isthmus. Branchiostegal rays 3 (rarely 4). Fins: dorsal of 3 (rarely 4) isolated, stout, serrated spines, each with triangular fin membrane, length of longest spine variable, usually 33.3–50.0% of head length, last spine very short, preceding, but not attached to soft rays, soft rays 11–13 (rarely 10 or 14), originating over or slightly in advance of anus; caudal with 12 rays, moderate and slightly forked; anal of 1 spine and 8–10 soft rays, the spine slightly shorter than last dorsal spine, lightly serrated and free from soft rays, origin of fin behind origin of soft dorsal fin and terminating under last soft dorsal ray; pelvics thoracic, situated on ventral surface below middle of pectorals, each with 1 strong spine and 1 soft ray, spine slightly longer than longest dorsal spine; pectorals large, length one-half that of head, situated a short distance behind gill opening. All fin spines can be rigidly locked in an erect position. Body naked, or plated, with variable number of vertical, oblong, bony plates on each side; up to 30 or more in saltwater specimens, few or none on specimens from fresh water; single, ventral, bony plate between and behind pelvic fins; lateral line high, complete. Vertebrae 31–33, rarely 29 or 30.

Colour Colour of adults variable above, silvery green, grey, olive, greenish brown, or sometimes mottled with dark markings, males (in British Columbia) occasionally almost black; sides paler and with silvery reflections, belly silvery. Fins pale but membranes often red. During breeding season, ripe males become brilliantly coloured with red on belly and flanks, and have bright blue eyes, whereas females assume pink tints on throat and belly. Body of the newly hatched larvae yellowish. Young fish bright silvery.

Systematic notes *Gasterosteus aculeatus* has been intensively studied in recent years and is now known to be separable into two distinct forms or possibly subspecies, or even species. Both are here regarded as forms of the species *G. aculeatus*. The marine form, called *trachurus*, has a complete series of lateral bony plates, is silvery coloured and of large size; the freshwater form, called *leiurus*, has few lateral bony plates, is olive coloured but mottled with light bars, and of smaller size. *Leiurus* remains in fresh water throughout its life, whereas *trachurus* migrates into fresh water in spring to spawn. The following biological information was derived from studies involving both forms, although it is now believed



that the two are reproductively isolated. For further information on this aspect *see* Hagen (1967). In some British Columbia populations the pelvic skeleton is absent or much reduced. The enormous variability within the species is mentioned by Hagen and McPhail (1970). In order to retain all the units in one category, as seems best because of the many taxonomic problems, Nelson (1971a) referred to the group as *Gasterosteus aculeatus* complex.

Distribution The threespine stickleback is nearly circumpolar (it is absent from the arctic Siberian coast and most of the arctic North American coast), widely distributed in the northern hemisphere in both salt and fresh waters. An anadromous and freshwater species, it is found in Europe from southern Greenland, Novaya Zemlya, northern Norway, and Iceland, southward to Spain, in the Mediterranean, and the Black Sea. It does not inhabit waters of the Caspian or Aral seas, nor the waters off the north coast of Siberia.

In North America it ranges from Chesapeake Bay north to the Hudson Bay region and Baffin Island, is apparently absent from arctic coasts of Northwest and Yukon territories and Alaska, but then occurs down the Alaskan and British Columbian Pacific coast to lower California.

In Canada it is a common species in Newfoundland waters and is generally distributed throughout the waters of the Atlantic provinces. Inland, it occurs in the St. Lawrence River, Ottawa River, the Lake Ontario basin, and in protected bays and rivers, but does not occur in the Great Lakes above Niagara Falls. It is present in many lakes, and most rivers and streams of the coastal area of British Columbia, and in the Fraser valley as far upstream as Kawkawa Lake, near Hope, B.C. It does not range north of Bering Strait in the Pacific but does occur on most offshore islands such as Queen Charlotte (where it reaches a very large size in one lake), Kodiak, and St. Lawrence islands.

It is absent from Saskatchewan and Alberta.

Biology The threespine stickleback spawns in fresh water, generally in June or July, but breeding occurs throughout the summer months, from April to September inclusive, in the Cowichan River in British Columbia. In central Europe, spawning takes place in waters of very low salinity from April to the end of July.

This species, unlike other members of the gasterosteid family, builds its nest on the bottom, preferably on a sandy area, in shallow water (Fish 1932). The nest is constructed of small twigs and plant debris, held together, as in the case of other sticklebacks, by the mucilaginous kidney secretion emitted by the male. The nest is barrelshaped, hollow, and with a smooth, circular opening in each end.

The male entices the female into the nest, carrying out his courtship dance in a series of zigzag motions, and touching the opening of the nest with his snout. When the nest is full of eggs, perhaps as a result of spawning with several females, the top of the nest is loosened, apparently for better ventilation. As many as 600 eggs have, on occasion, been found in one nest. The eggs are yellowish, and semiopaque, each 1.5–1.7 mm in diameter, although the size does vary somewhat with locality (Vrat 1949). They are laid in clusters, adhesive to each other. Hatching occurs in 7 days at 66.2° F (19° C) (Breder and Rosen 1966). The male guards and fans the nest, and continues to guard the newly hatched fish until they are able to care for themselves.

Newly hatched larvae vary slightly in size in different localities. Massachusetts specimens measured 4.2–4.5 mm in length (Kuntz and Radcliffe 1917), those from California locations 4.71–4.91 mm standard length (Vrat 1949), and Jones and Hynes (1950) noted that newly hatched fish were 5 mm long in England.

In the Birket River in England, studies of the otoliths indicated that the stickleback probably does not live longer than 3½ years and that growth is rapid during the first year, slowing considerably in the second year. At the end of the first summer, size ranged approximately 15–33 mm in total length; at the end of the second summer 25–50 mm total length; and at the end of the third summer 35–55 mm total length (*see* Jones and Hynes 1950, for further data). Sexual maturity is attained during the first year. Maximum size attained is about 3 inches (76 mm) in fresh water, but some specimens may grow to 4 inches (102 mm) in length. Lengths in excess of this are said to be attained by St. Lawrence Island fish. Studies of this species in Alaska revealed that the life span in Karluk and Bare lakes is about 2½ years, during which time they spawn once, and possibly twice.

In Newfoundland the threespine stickleback is found in most shallow waters, and is tolerant of marine, brackish, and fresh water. It is common in drainage areas of tidal marshes and has been found on some banks off Nova Scotia and the Maine coast, where they have been swept out to sea. Greenbank and Nelson (1958) reported evidence of large numbers along shoals and some on the surface in the centre of Karluk and Bare lakes, and even a few in deep water. In Hudson Bay this stickleback lived not only in the tidal pools, creeks, estuaries, or shore waters, but occurred as far as 1 mile from the mainland (Cox 1922).

The threespine stickleback is a voracious creature, feeding on various kinds of worms, small crustaceans, aquatic insects, and larvae, drowned aerial insects, and eggs and fry of fish, including their own species (Hynes 1950). They will eat essentially any available animal foods.

Despite its forbidding dorsal and pelvic spines, the threespine stickleback is preyed upon by a variety of creatures, such as fish-eating birds (e.g., American mergansers), as well as larger inshore fishes, such as salmon and trouts (British Columbia). The presence of lateral, armourlike plates, particularly on marine representatives, is thought to provide a measure of protection against predation.

The threespine stickleback seems prone to parasitic infestations, some of which are intermediate stages of parasites that reach maturity in predatory ducks and other fish-eating birds. Wardle (1933) reported *Ligula intestinalis* and *Schistocephalus solidus* from this species. Bangham and Adams (1954) examined 35 specimens from three localities in British Columbia. They found parasites only in those from Lakelse Lake, 31 of the 32 fish examined being infected. Parasites included trematodes, copepods, nematodes, molluscs, acanthocephalans, and cestodes. Dechtiar (personal communication) reported infection in a specimen from Hawley Lake, Ont., (near Hudson Bay) as follows: infections in eyes by larvae of strigeid fluke *Diplostomulum* sp. (such an infection can result in blindness), and specimens of the pleurocercoid stage of the tapeworm *Schistocephalus solidus* in the body cavity. Hoffman (1967) listed many species of parasites in the threespine stickleback from waters of North America, England, Europe, and the USSR.

Relation to man The threespine stickleback is well known to behaviourists and psychologists, as well as fishery biologists, because of its wide use as a laboratory animal. Not only will this small fish build a nest and spawn in an aquarium but sexually mature males and females can be induced to perform their mating rituals by being presented with appropriately shaped dummies simulating the opposite sex.

Threespine sticklebacks may, when abundant, serve as an important forage species for trout and other predaceous fishes, and also for fish-eating birds.

Nomenclature

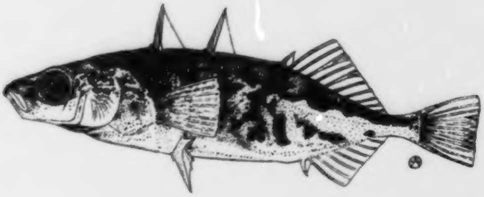
Gasterosteus aculeatus — Linnaeus 1758: 295 (type locality Europe)
Gasterosteus aculeatus Fabricius — Richardson 1836: 54
Gasterosteus biaculeatus (Pennant) — Richardson 1836: 56
Gasterosteus serratus — Lord 1866a: 127
Gasterosteus Atkinsii — Bean 1880a: 67
Gasterosteus cataphractus Pallas — Bean 1884b: 353
Gasterosteus microcephalus Girard — Bean 1884b: 353
Gasterosteus bispinosus Walbaum — Bean 1903b: 340
Gasterosteus cuvieri Girard — Halkett 1913: 73
Gasterosteus atkinsii Bean — Halkett 1913: 73
Gasterosteus insculptus Richardson — Jordan, Evermann, and Clark 1930: 237
Gasterosteus atkinsi Bean — Jordan, Evermann, and Clark 1930: 238

Etymology *Gasterosteus* — belly bone, referring to the bony ventral plate; *aculeatus* — spined.

Common names Threespine stickleback, twospine stickleback, banstickle, spantickle, saw-finned stickleback, pinfish, tiddler, common stickleback, European stickleback, eastern stickleback, New York stickleback. French common name: *épinoche à trois épines*.

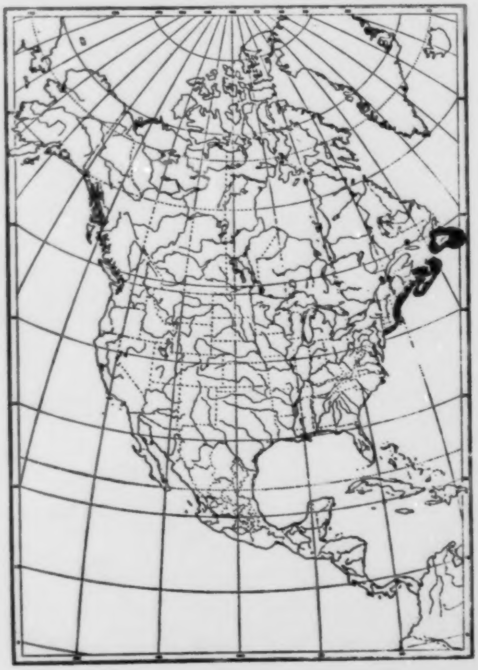
BLACKSPOTTED STICKLEBACK

Gasterosteus wheatlandi Putnam



Description Body rather stout, compressed, average length 2 inches (51 mm) long, body depth 20–25% of total length; caudal peduncle slender, without lateral keel. Head 22.2–28.6% of total length, compressed; eye diameter 28.6–33.3% of head length; mouth small, lower jaw projecting; teeth on jaws minute, sharp. Gill rakers 15, long, slender; gill membranes united to isthmus. Branchiostegal rays 3. Fins: dorsal of 3 isolated, and lightly serrated, spines, each with triangular membrane, first 2 spines long, second usually longest, 33.3–50.0% length of head, third very short and immediately in advance of, but not attached to soft rays of dorsal fin, soft rays 9 (occasionally 10 or 11), longest at origin of fin and about equal to length of second dorsal spine, origin of soft rays immediately over anus; caudal moderate, truncate, 12 rays; anal fin of 1 spine and 7 soft rays, the spine strongly curved, equal to or shorter than third dorsal spine, immediately preceding and joined to the soft rays, origin behind that of soft dorsal fin and terminating below end of soft dorsal rays; pelvic of 1 strong spine and 2 rays, the spine strongly serrated and with strong basal cusps on each side, these pointed cusps situated dorsally and ventrally at base of spine; pectorals large, 9 or 10 rays, over one-half length of head, inserted on sides a little behind gill opening. All spines can be locked in erect position. No scales; 6–11 vertical, bony plates, anteriorly on sides of body, none posteriorly; a single, ventral, bony plate on lower surface, between and behind pelvic fins, a lateral plate extending dorsally from anterior base of pelvic fins; lateral line high. Vertebrae 27–29.

Colour Adult fish are yellow, or greenish yellow, with dark spots on the sides; belly silvery. Colour is more conspicuous on spawning fish; ripe males have orange pelvic fins and become gold in colour.



Distribution The blackspotted stickleback, a North American species, occurs in marine coastal localities along the Atlantic coast from Newfoundland south to New York. It tolerates brackish water and in one instance was recorded from fresh water—from inside the mouth of the Jacquet River, Restigouche County, N.B.

In Canada it has been reported from various sites in Quebec, Anticosti Island, other localities in the Gulf of St. Lawrence, New Brunswick and in southern Newfoundland. A record from Rivière Gethsémanie, Que., on the north shore of the Gulf of St. Lawrence (a location 100 miles north of Port au Port, Nfld.) appears to be the northern limit of range. Although not specifically reported, it undoubtedly occurs in Nova Scotia and Prince Edward Island.

This species has frequently been confused with the threespine stickleback, *G. aculeatus*, with the result that distributional records are sometimes in doubt. It occurs sympatrically with *G. aculeatus*, whose range overlaps that of *G. wheatlandi*.

Biology Accounts of the biology of the blackspotted stickleback have long been confused with those of the threespine stickleback, *G. aculeatus*, and little was definitely known of its life history until quite recently. Breder and Rosen's (1966) account of the behaviour of this species refers to the abovementioned threespine stickleback. However, McInerney (1969) presented a fine descriptive account of the breeding of *G. wheatlandi* and noted that although the reproductive biology closely parallels that of *G. aculeatus*, it differs in at least three significant ways, thus ensuring reproductive isolation: *wheatlandi* spawns in brackish water; males have a different colour pattern; and the leading–following reactions of males and females are different and apparently incompatible.

It is assumed that spawning takes place in late spring, slightly later than that of the threespine stickleback, whose habitat it shares. Both the blackspotted and the threespine sticklebacks were taken in spawning condition in collections made during the period May 5–June 9, 1961, when it was observed that the threespine stickleback was perhaps nearing the end of the spawning process, and the blackspotted stickleback just beginning to spawn (Perlmutter 1963). Scott and Crossman (1964) noted that in natural conditions in Newfoundland, brightly coloured, breeding females were found in brackish waters.

A nest is constructed as with the other gasterosteids. The courtship display is similar to that of the threespine and includes the zigzag motion described for that species. The male leads the female to the nest, places his snout in the entrance, retreats and allows the female to enter. He induces spawning by running his snout along the sides of the female, who deposits her ova and exits. Fertilization is quickly accomplished for the male releases the sperm as it swims through the nest. The female swims away and the male cares for the nest and aerates the eggs (fanning).

Results from a sample of 20 ripe females indicated that the number of eggs for each female ranged from 171 to 272, and the egg size varied from 1.2 to 1.5 mm in diameter. The possibility that some of the females were spawning at the time of capture and that some had not commenced to deposit eggs could account for the variation in the number of eggs per female noted by Scott and Crossman (1964).

Rate of growth of this species is relatively unknown, as is its life span. The mature female is larger than the male (Reisman 1968). The largest specimen collected in Newfoundland measured 2.5 inches (64 mm) total length. Maximum size reported for the Atlantic coast area is 3 inches (76 mm).

The blackspotted stickleback frequently leads a semipelagic existence, swimming near floating seaweed. Perlmutter (1963) notes that in the waters of Long Island, New York, this species was found in company with the threespine stickleback in 3 feet or less water, over a coarse, gravelly bottom.

Information on the food of this species appears to be rare or nonexistent; and neither is there reliable information regarding parasitic infections.

Relation to man The blackspotted stickleback could be used as a laboratory animal for experimental purposes as demonstrated by McInerney, but is less suitable for this purpose because of its restricted distribution and availability.

Nomenclature

Gasterosteus Wheatlandi —Putnam 1866: 4 (type locality Nahant, Mass.)
Gasterosteus gladiunculus — Kendall 1896: 623
Gasterosteus bispinosus cuvieri (Girard) — Jordan and Evermann 1896–1900: 749
Gasterosteus biaculeatus Shaw — Jordan and Evermann 1896–1900: 748
Gasterosteus bispinosus — Cox 1923: 147
Gladiunculus wheatlandi (Putnam) — Hubbs 1929: 2
Gasterosteus biaculeatus Penn., Sh. et Mitch. — Hubbs 1929: 3 (as used by Cuvier and Valenciennes)
Gasterosteus bispinosus Walbaum — Hubbs 1929: 5

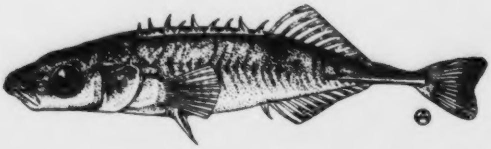
For a discussion of the nomenclature of this species, *see* Hubbs (1929).

Etymology *Gasterosteus* — belly bone, referring to the bony ventral plate; *wheatlandi* — after Dr R. H. Wheatland, who collected the first specimens at Nahant, Mass., in 1859.

Common names Blackspotted stickleback, twospined stickleback, twospine stickleback, blackspot stickleback. French common name: *épinoche tachetée.*

NINESPINE STICKLEBACK

Pungitius pungitius (Linnaeus)



Description Body small, slender, and compressed, length 2.5 inches (64 mm), greatest depth 15.4% of total length, tapering to a very slender caudal peduncle, which is broader than deep; caudal peduncle usually with a well-developed, lateral keel on each side, but keel may be poorly developed or absent. Head quite large, about 25% of total body length; eye large, its diameter 22.2–28.6% of head length; mouth small, oblique, with fleshy lips, lower jaw projecting; teeth slightly curved, sharp, in single series. Gill membranes united but entirely free from isthmus. Branchiostegal rays 3. Fins: dorsal of 9 (8–11), short, isolated spines, directed backward, each with triangular fin membrane, spines usually 1.0–1.5 mm long, inclined alternately to left and right, nearly uniform in height, last spine slightly larger, spines begin above gill opening, and extend back to soft dorsal rays, depressible in shallow groove along back, soft rays 9–11, first rays twice height of spines tapering off posteriorly; caudal rounded, 12 (rarely 13) soft rays; anal with 1 spine and 8–10 (rarely 11), soft rays, tapering off posteriorly like soft dorsal rays, located under soft dorsal rays, the spine slightly longer than dorsal spines; each pelvic fin reduced to single, strong spine, 25.0–33.3% of length of head, and usually 1 soft ray located under middle of pectorals; pectorals large, located on sides behind gill openings and extending to sixth dorsal spine. All spines can be locked in an erect position. No true scales; small, bony plates usually along anterior portion of lateral line and at bases of dorsal and anal fins and on caudal peduncle keels; a single, small, bony plate on ventral surface between and behind pelvic fins; lateral line inconspicuous. Vertebrae 32–34 (rarely 30, 31, or 35).

Colour Pale green, grey, or olive above, strongly pigmented with irregularly arranged dark bars or blotches; silvery below. During breeding season reddish tints appear, particularly about the head. Breeding males may have jet black belly and white pelvic fin membranes.

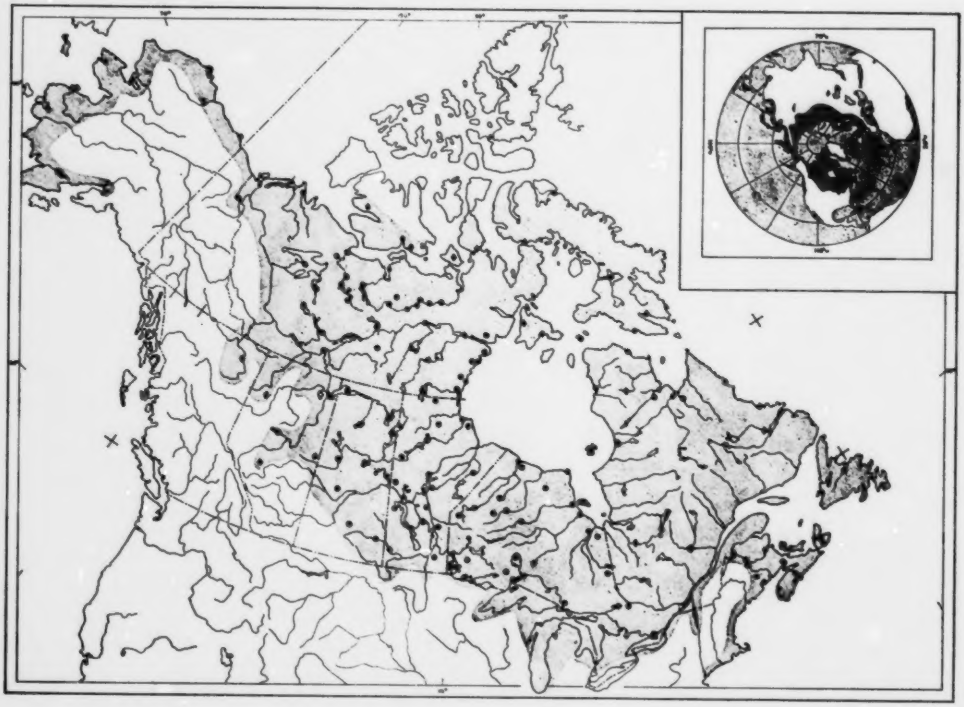
Systematic notes McPhail (1963), in an intensive study of the North American species, concluded that two distinguishable forms existed, a Bering Strait form, which occurs in coastal waters throughout arctic Canada south along the Atlantic coast, including the Maritime Provinces; the second is the Mississippi form which occurs throughout the inland fresh waters. He concluded that the degree of difference did not warrant subspecific distinction. In some localities in the Wood Buffalo National Park region, the pelvic skeleton is absent in a high proportion of the individuals (Nelson 1971b).

Distribution The ninespine stickleback is generally distributed in fresh and salt waters throughout the northern hemisphere. In marine situations it is usually confined to shore areas. It is found along the coasts of northern Europe, along the shores of the Baltic, and is also common in inland waters.

In North America, the ninespine stickleback ranges from the New Jersey Atlantic coast, north along the entire Atlantic and arctic coasts, westward to the Aleutian Islands of Alaska, and south on the Alaskan Pacific coast to the Kenai Peninsula side of Cook Bay, but not south on the Pacific coast. Inland it ranges from the southern Great Lakes basin, (and Crooked Lake, Indiana, in the Mississippi River drainage basin) north in central Canada to the arctic coast.

In Canada, it occurs in all provinces and territories. It is found more or less throughout each of the four Atlantic provinces, and is restricted to southern and western portions of inland Quebec but occurs in all coastal waters; throughout Ontario, Manitoba, most of Saskatchewan, and eastern and northern Alberta, northern British Columbia, north to the Arctic Ocean. It is often very abundant in salt water or brackish pools along the shores of Hudson and James bays.

Biology The ninespine stickleback spawns in fresh water in summer and is reported on occasion to spawn more than once in a season. No evidence, however, of autumn spawning has been found. Nelson (1968a) noted that it spawned only in fresh water although it has a relatively high salinity tolerance, but not as high as that of *Gasterosteus*. Both sexes are aggressive in breeding season. The male, all black in colour and less aggressive than the female when he begins his nest building, selects a site among the weeds and constructs a nest, usually off the bottom, in the plants, using fragments of aquatic vegetation bound together (gluing) by the threadlike, kidney secretion that hardens on contact with water,



as with other gasterosteids (McKenzie and Keenleyside 1970).

The nest is tunnel-shaped and has an opening at each end. When construction is completed, the male begins his courtship of the female, with a series of quick dancing movements. The female is enticed into the nest, pauses to deposit a cluster of eggs, numbering 20–30, and departs from the opposite exit. She is chased away by the male, who immediately enters the nest and fertilizes the eggs, swimming without stopping through the tunnel. The nest is guarded by the male who engages in considerable fanning at the entrance, causing a current to flow through the nest and aerate the eggs within.

As the young hatch, the male has been observed removing the egg cases from the nest (Morris 1958). As many as seven females may be encouraged to deposit eggs in one nest. While caring for the incubating young, the male may build a second nest. When the young fish are about 2 weeks old and about 15 mm long, the male can no longer control their wanderings and the small fish move into open water.

Jones and Hynes (1950), in their comprehensive study of the age (using otoliths) and growth of this species in two rivers in England, found that most mature in their first year. Growth is very rapid during the first year, slowing considerably in following years. Length of life is about 3½ years. Maximum length of first-year fish has been recorded as 38–46 mm, second-year fish 45–48 mm, and third-year fish 48–55 mm.

In the Atlantic coast region the ninespine can grow to a size of 3 inches (76 mm), but is not usually over 2 inches (51 mm) long.

The ninespine stickleback may move freely into open water. During dragging operations in the Shelter Bay region of Lake Superior, Ont., a large number were taken at 38–42 fathoms (few at other depths). Although this species can survive in waters of relatively high salinity, in Newfoundland, where it is widespread, it was found only in fresh water. In coastal regions it is usually an estuarine species, moving into creeks and streams to spawn.

The food of this small, pugnacious species consists of aquatic insects and small crustaceans. Hynes (1950) study of the food of this species in England revealed that the diet is similar to that of *Gasterosteus aculeatus*, consisting of crustaceans and aquatic insects, and, during breeding season only, eggs and larvae of their own species. In fresh water, small fish fry and fish eggs are eaten.

Bangham (1955) recorded the acanthocephalan *Neoechinorhynchus rutili* in the one specimen he examined from South Bay on Lake Huron. Cooper (1918) recorded *Schistocephalus solidus* from specimens caught in Bernard Harbour, N.W.T. Hoffman (1967) listed many species of parasites from the species, mainly records from Russia and Europe.

Relation to man When in abundance the ninespine stickleback is of considerable importance, forming a large part of the diet of other fishes. The reports by Dryer (1966) of large numbers in Lake Superior, suggested that it may be a more important forage species than had previously been supposed. Dymond (1926) noted that "In Lake Nipigon it is one of the most abundant of the smaller fishes, and appears to form no inconsiderable part of the food of the pike perch." He also noted that it was eaten by brook trout, lake trout, yellow perch, and ling or burbot. Ninespine sticklebacks (and ciscoes) were the main food items in the diet of walleyes in Lac la Ronge, Saskatchewan (Rawson 1957).

It may occur in great abundance in sloughs and shallow shore waters of northern Canada. Richardson (1836) noted that "in 1820 many sledge loads were taken from a small pond in the vicinity of Cumberland House for the purpose of feeding the dogs."

Nomenclature

Gasterosteus pungitius	— Linnaeus 1758: 296 (type locality Europe)
Gasterosteus concinnus (Richardson)	— Richardson 1836: 57
Gasterosteus occidentalis (Cuvier)	— Richardson 1836: 58
Gasterosteus occidentalis Brevort	— Adams 1873: 255
Pygosteus Dekayii Brevort	— Adams 1873: 305
Gasterosteus pungitius L.	— Cox 1896b: 68
Gasterosteus dekayi Agassiz	— Jordan and Evermann 1896–1900: 746
Pygosteus pungitius (Linnaeus)	— Bean 1903b: 338
Gasterosteus nebulosus Agassiz	— Bean 1903b: 338
Pygosteus pungitius Eigenmann	— Bean 1903b: 338
Gasterosteus occidentalis (Cuvier and Valenciennes)	— Jordan, Evermann, and Clark 1930: 239
Pungitius pungitius (Linnaeus)	— Jordan, Evermann, and Clark 1930: 239

Etymology *Pungitius* — meaning pricking.

Common names Ninespine stickleback, nine-spined stickleback, stickleback, ten-spine stickleback, pinfish, tiny burnstickle. French common name: *épinoche à neuf épines.*

Suggested Reading — Gasterosteidae

Barker, E. E. 1918. The brook stickleback. Sci. Month. 6: 526–529.

Dawson, J. W. 1859. On a new species of stickleback *(Gasterosteus gymnetes)*. Can. Natur. Geol. 4: 322–324.

Greenbank, J., and P. R. Nelson. 1958. Life history of the threespine stickleback *Gasterosteus aculeatus* Linnaeus in Karluk Lake and Bare Lake, Kodiak Island, Alaska. U.S. Fish Wildl. Serv. Fish. Bull. 153, Vol. 59: 537–539.

Hagen, D. W. 1967. Isolating mechanisms in threespine sticklebacks *(Gasterosteus)*. J. Fish. Res. Bd. Canada 24: 1637–1692.

Hansen, D. F. 1939. Variation in the number of spines and rays in the fins of the brook stickleback. Trans. Ill. State Acad. Sci. 22: 207–212.

Heuts, M. J. 1947. The phenotypical variability of *Gasterosteus aculeatus* in Belgium. Verh. Kon. Vlaam Acad. Wetensch. 9 n. 25: 1–63.

Hubbs, C. L. 1929. The Atlantic American species of the fish genus *Gasterosteus*. Occas. Pap. Mus. Zool. Univ. Mich. 200: 9 p. + 2 pl.

Hynes, H. B. N. 1950. The food of fresh-water sticklebacks *(Gasterosteus aculeatus* and *Pygosteus pungitius)*, with a review of methods used in studies of the food of fishes. J. Anim. Ecol. 19: 36–58.

Jacobs, D. L. 1948. Nesting of the brook stickleback. Proc. Minn. Acad. Sci. 16: 33–34.

Jones, J. W., and H. B. N. Hynes. 1950. The age and growth of *Gasterosteus aculeatus*, *Pygosteus pungitius* and *Spinachia vulgaris*, as shown by their otoliths. J. Anim. Ecol. 19: 59–73.

Krueger, W. H. 1961. Meristic variation in the fourspine stickleback, *Apeltes quadracus*. Copeia 1961: 442–450.

Lindsey, C. C. 1962. Experimental study of meristic variation in a population of threespine sticklebacks, *Gasterosteus aculeatus*. Can. J. Zool. 40: 271–312.

McInerney, J. E. 1969. Reproductive behaviour of the blackspotted stickleback, *Gasterosteus wheatlandi*. J. Fish. Res. Bd. Canada 26: 2061–2075.

McKenzie, J. A., and M. H. A. Keenleyside. 1970. Reproductive behaviour of ninespine sticklebacks (*Pungitius pungitius* (L.)) in South Bay, Manitoulin Island, Ontario. Can. J. Zool. 48: 55–61.

McPhail, J. D. 1963. Geographic variation in North American ninespine sticklebacks, *Pungitius pungitius*. J. Fish. Res. Bd. Canada 20: 27–44.

Morris, D. 1958. The reproductive behaviour of the ten-spined stickleback *(Pygosteus pungitius* L.). Behaviour Suppl. 6. E. J. Brill, Leiden. 154 p.

Nelson, J. S. 1968. Salinity tolerance of brook sticklebacks, *Culaea inconstans*, freshwater ninespine sticklebacks, *Pungitius pungitius*, and freshwater fourspine sticklebacks, *Apeltes quadracus*. Can. J. Zool. 44: 663–667.

1969. Geographic variation in the brook stickleback, *Culaea inconstans*, and notes on nomenclature and distribution. J. Fish. Res. Bd. Canada 26: 2431–2447.

1971a. Comparison of the pectoral and pelvic skeletons and of some other bones and their phylogenetic implications in the Aulorhynchidae and Gasterosteidae (Pisces). J. Fish. Res. Bd. Canada 28: 427–442.

1971b. Absence of the pelvic complex in ninespine sticklebacks, *Pungitius pungitius*, collected in Ireland and Wood Buffalo National Park Region, Canada, with notes on meristic variation. Copeia 1971: 707–717.

NELSON, J. S., and F. M. ATTON. 1971. Geographic and morphological variation in the presence and absence of the pelvic skeleton in the brook stickleback, *Culaea inconstans* (Kirtland), in Alberta and Saskatchewan. Can. J. Zool. 49: 343–352.

REISMAN, H. M. 1963. Reproductive behaviour of *Apeltes quadracus*, including some comparisons with other gasterosteid fishes. Copeia 1963: 191–192.

REISMAN, H. M., and T. J. CADE. 1967. Physiological and behavioral aspects of reproduction in the brook stickleback, *Culaea inconstans*. Amer. Midland Natur. 77: 257–295.

SCHWARTZ, F. J. 1965. Age, growth and egg complement of the stickleback *Apeltes quadracus* at Solomons, Maryland. Chesapeake Sci. 6: 116–118.

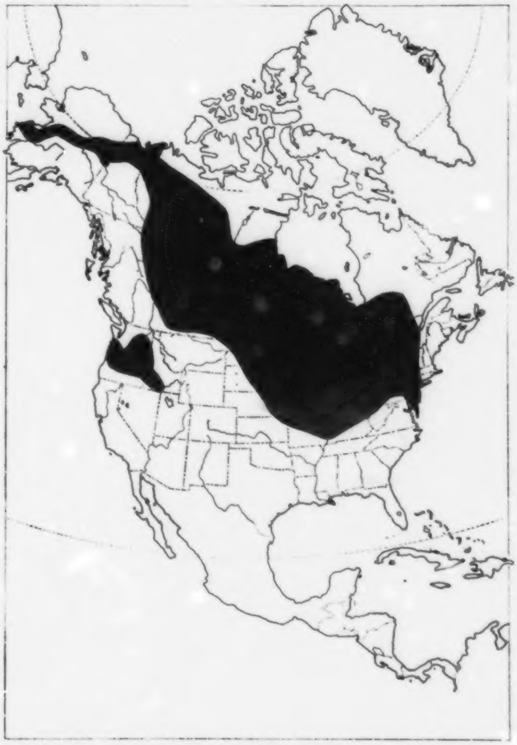
THOMAS, B. O. 1962. Behavioral studies of the brook stickleback, *Eucalia inconstans* (Kirtland). Amer. Zool. 2: 452.

WINN, H. E. 1960. Biology of the brook stickleback *Eucalia inconstans* (Kirtland). Amer. Midland Natur. 63: 424–438.

THE TROUT-PERCHES —
Order Percopsiformes (Salmopercae, Amblyopsiformes)

These are small, robust-bodied fishes with relatively large heads, weak to moderately strong jaws and small teeth. The upper jaw is bordered by the premaxillaries. Branchiostegal rays 6 or 7. The dorsal and anal fins are preceded by 0–4 spines that, when present, may be quite soft; caudal fin supported by a somewhat peculiar hypural structure consisting only of 3 hypurals and in which the last 2 vertebral units are fused and slightly upturned; pelvic fins with or without a small spine and with 7 or 8 soft rays, abdominal to subabdominal in position, the pelvic bones attached to the postcleithra (when present). Physoclists.

The percopsiform fishes constitute a small group of North American freshwater fishes currently considered to embrace 3 genera and 5 species, grouped into 3 families: Amblyopsidae, Aphredoderidae, and Percopsidae. Only 1 family, Percopsidae, occurs in Canadian waters.



North American Distribution of the Trout-perches

Trout-Perch Family — Percopsidae

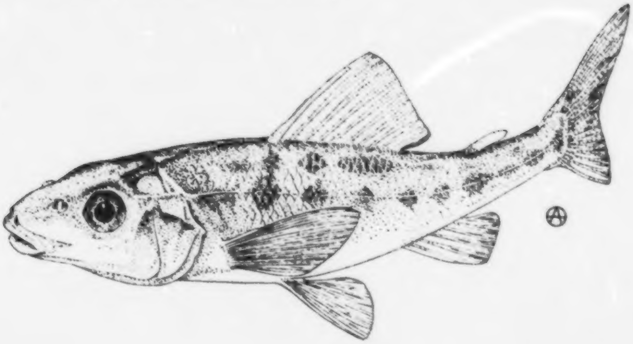
The trout-perches, so-called because they possess characteristics exhibited by both the salmons and the perches, have large heads; subterminal lower jaws; premaxillaries nonprotractile, forming border of upper jaw; dorsal and anal fins each preceded by 1 or 2 spines; an adipose dorsal fin inserted posteriorly, over caudal peduncle; pelvic fins each with a weak spine and 7 or 8 soft rays, the anterior portion of the pelvic fin overlapped by pectoral fin. Scales are small, and weakly ctenoid.

These are small, dark-spotted, silvery fishes, essentially bottom feeders, living in streams and lakes of temperate and northern North America. The family contains only 1 genus, *Percopsis*, and 2 species, *P. transmontana* (*Columbia transmontanus* is a synonym) and *P. omiscomaycus*. Only the latter species occurs in Canadian waters.

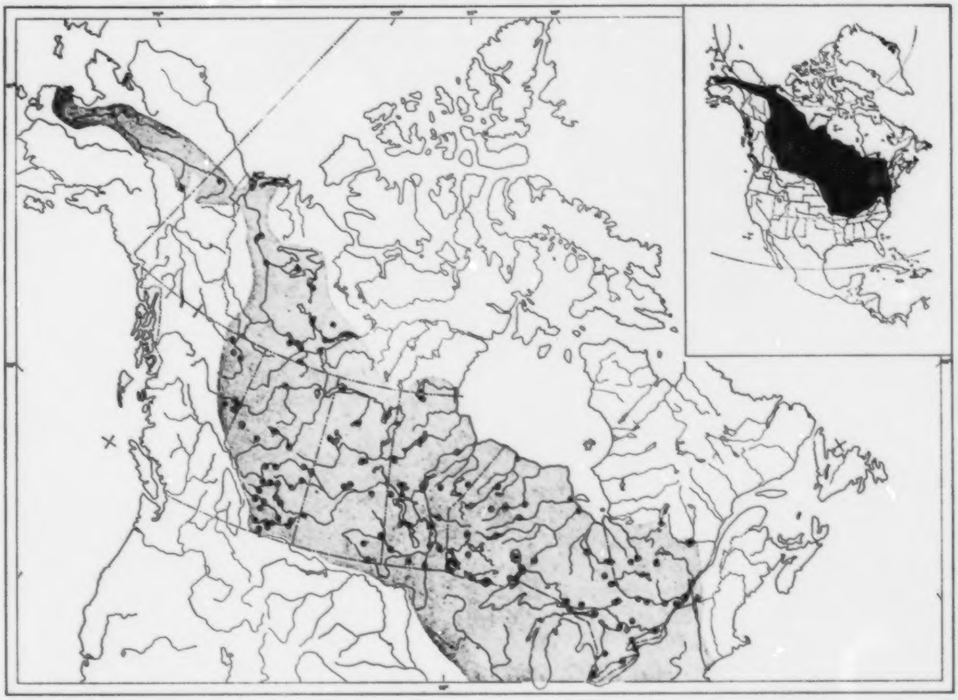
Known in North America from Eocene to Recent.

TROUT-PERCH

Percopsis omiscomaycus (Walbaum)



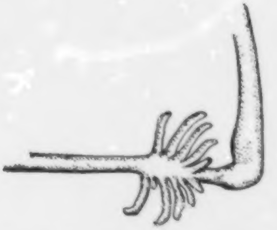
Description Body small, average length 3–4 inches (76–102 mm), terete, distinctly thicker anteriorly. Head relatively large and somewhat conical, 22.5–26.6% of total length; eye relatively large, its diameter 22.1–27.2% of head length; snout long, 29.6–38.0% of head length, and overhanging small mouth; interorbital wide, 17.5–28.9% of head length; mouth ventral, adapted for bottom feeding, the gape terminating well in advance of eye; teeth brushlike, in bands on upper and lower jaws only, band several teeth wide anteriorly, outer teeth larger and more widely spaced than inner teeth, longest tooth about 0.4 mm. Gill rakers short, mere mounds of tissue with embedded teeth, 2–4 on upper arm, 6–9 on lower arm. Branchiostegal rays 5,5 (1 specimen), 6,6 (18 specimens), but McAllister (1968) examined 50 specimens and reported 6(48), 7(2). Fins: small adipose dorsal present; dorsal 1, height 16.8–20.8% of total length, originating behind origin of pelvic fins, rays 2 undivided (soft spines), and 9(2), 10(26), or 11(21) soft rays; caudal distinctly forked, principal rays 17(1) or 18(18); anal 1, its base moderate, height less than dorsal, 1 undivided ray and 5(1), 6(18), 7(8), or 8(1) divided, soft rays; pelvics thoracic, inserted behind dorsal origin, and broadly overlapped by pectorals, rays 8(5) or 9(25); pectorals well developed, length 15.9–19.7% of total length, rays 12(3), 13(8), 14(18), or 15(1). Scales weakly ctenoid, with a single row of ctenii,



43–60 (usually 44–50) in lateral line. Pyloric caeca 10–14. Vertebrae 33 or 34.

Colour Overall colouration silvery, often appearing to be partially transparent; 5 distinct rows of black spots overlay the background colour, the first row of some 9–12 vague or diffuse marks occur along the midline of the back, these sometimes diffuse into each other; a row of 7–12 spots, sometimes only weakly developed, also occur high on the side, between the lateral midline and the back, and finally, the most conspicuous row of 10 or 11 marks along the midline of the side.

Systematic notes The trout-perch is unique among Canadian freshwater fishes in the number and arrangement of the pyloric caeca. These vary from 10–14 and are arranged along the gut as shown in the accompanying figure.



The number of caeca appears to be very stable. Studies of specimens from lakes Erie, Superior, Attawapiskat, Ont., and Heming, Man., revealed no differences between sexes, sizes, or localities. The pyloric caeca can be useful in identifying trout-perch remains in stomach contents since, being resistant to digestive enzymes, they are resistant to the digestive system of their predator and are recognizable after most other ingested tissues are in an advanced state of digestion.

Distribution The trout-perch is widely distributed in lakes and streams throughout central and northern North America. It ranges from Quebec, north and west to Alaska. In the United States, it ranges northwest from West Virginia, Kentucky, Missouri, and Kansas on the south, but is generally not common south of the Great Lakes.

In Canada it occurs from central and western Quebec, through Ontario, in all of the Great Lakes, in Manitoba, Saskatchewan, Alberta, and northeastern British Columbia to the Yukon and Northwest territories. In Alaska it occurs only in the Porcupine River and the Yukon River, and from about Eagle to the mouth of the Andreafsky River, but not in the upper Yukon River system in Yukon Territory.

The trout-perch is thought to have repopulated North America in postglacial times from a refugium in the Mississippi valley.

Biology Trout-perch usually spawn in the early spring, most often in May in inland waters, although few precise observations have been reported. Magnuson and Smith (1963) noted that first spawning runs occurred in Red Lake, Minn., after mean air temperature remained above 50° F (10° C) for 44–46 days. Lawler (1954) provided observations of fish aggregating in shallow rocky streams in north-central Manitoba and we have captured ripe fish in May in the lower reaches of streams in Ontario. But spawning has also been reported to occur over a sand and gravel bottom in the shallow (0–4 feet) shore waters of Lake Erie and Red Lake, Minn. The lake-spawning populations seem unique in that spawning was prolonged and in Lake Erie, in 1946, was observed to extend from May to August. Ripe males and females were caught as early as May 9, and partly spent males and females were caught on August 15, 1946. In Red Lake, spawning was considered to have extended from June 5 to August 23 in 1956 and 1957, and the peak of the run occurred from June 25 to July 4, 1956 (Magnuson and Smith 1963). In our opinion most eastern Canadian populations spawn in streams in May and return to the lakes after spawning. We noted that at Beaverlodge Lake, east of Great Bear Lake, in the Northwest Territories, specimens of trout-perch taken on June 24–29 were sexually mature but had not spawned. The specimens were smaller than those found in southern Canada.

The eggs are relatively large for such a small species. Fish (1932) gave egg diameters of 1.36–1.85 mm for Lake Erie specimens and noted that unfertilized eggs contained numerous oil globules but that fertilized eggs usually contained only a single, consolidated, oil globule of about 0.7 mm diameter. Lawler (1954) gave egg diameters of 1.25–1.45 mm for Manitoba specimens. He also reported that egg numbers for 11 fish varied from 240 to 728 eggs, with an average of 349 eggs per individual. There is little information on the rate of development, although Langlois (1954) noted that eggs hatched within 20 days. Fish (1932) figured and described four stages in the development of larval *Percopsis* from 6.0–35.5 mm long.

Kinney (1950) suggested that males and females can be sexed externally, using the diameters of, and the distances separating, the anal and urinogenital apertures, but we have been unable to employ successfully this character, particularly with ripe or spawning trout-perch.

The growth characteristics of trout-perch have not been well studied, except by Magnuson and Smith, who successfully used scales for calculating growth, although Kinney (1950) was unable to age trout-perch using scales. No one seems to have published on the use of otoliths for aging trout-perch, although the otolith is large and would seem to offer promise for this purpose but Lawler (personal communication) used otoliths and considered them not useful for age determinations. He also obtained satisfactory results using scales. Kinney used arithmetic probability paper to age Lake Erie specimens and concluded that spawning occurred at age 1, that large females and most males die after spawning, but that a few females and very few males live to spawn twice. Magnuson and Smith have shown that females are larger than males at all ages and live longer than males. Males live to age 3, females to age 4.

Magnuson and Smith provided data on total lengths (in mm) at each age group of 1 to 4, for both sexes. The following figures were derived from their data: age 1 (M=50.8, F=51.4); age 2 (M=88.2, F=92.2); age 3 (M=103.5, F=108.3); age 4 (F=114.7).

The largest specimens known to us occur in Lake Ontario where total lengths to 6 inches (152 mm) are attained.

In Ontario and Quebec the trout-perch is found mainly in lakes, resorting to streams only to spawn (with exceptions already noted). Under these conditions the species is seldom seen, for it appears to stay in deeper water during the day, moving into shallow shore waters after dark. It is seldom caught during lake surveys, except by night seining, although it can be caught by otter trawls in daytime. Density figures or population estimates in Heming Lake, Man., were given by Lawler and Fitz-Earle (1968), who obtained estimates of numbers of trout-perch of 711,451 and 883,148, or 1186–1472 per acre.

Although typically a lake species in the east, it occurs in shallow, sometimes turbid, streams in Manitoba, Saskatchewan, and possibly in Alberta and the Northwest and Yukon territories.

We know little about the food of the trout-perch since few studies have been undertaken. We assume that the characteristic inshore movement after dark is for purposes of getting food. Those studies that have been undertaken, primarily by Kinney in Lake Erie, indicate that insect larvae, especially of midges (Chironomidae), and of mayflies (Ephemeroptera), were prominent in the diet during July, although in January and February large trout-perch had eaten darters and minnows. In Lake Nipigon, Dymond (1926) noted that insect larvae and amphipods were the chief food items in stomachs.

Trout-perch should be regarded as a most important forage fish. Yellow walleye, northern pike, burbot, lake trout, brook trout, sauger, yellow perch, and even freshwater drum have been reported to eat them. Possibly the first four are the more important natural predators. Magnuson and Smith regarded the yellow walleye as the most important predator in their studies at Red Lake, Minn., and northern pike was the most important predator (63 trout-perch in a single stomach) in the study at Heming Lake, Man., reported by Lawler (1954).

Trout-perch harbour a wide variety of parasites, including trematodes, cestodes, nematodes, acanthocephalans, and crustaceans, which were listed in detail by Bangham and Hunter (1939), Bangham (1955), and Hoffman (1967). Bangham and Hunter's observations were made on Lake Erie populations and they remarked that the trout-perch was the natural host of a relatively large number of parasites and many specimens had moderately heavy infestations.

The trout-perch is also the most important second intermediate host of the cestode parasite *Triaenophorus stizostedionis* (*see* Miller 1945). The eggs of the adult tapeworm are shed into the water, hatch and become coracidia, and are eaten by the copepod *Cyclops bicuspidatus* to become procercoids within the copepod. If the copepod is ingested by a trout-perch, the parasite encysts in the visceral and parietal peritoneum and is then known as a pleurocercoid. The life cycle is completed when the infected trout-perch is consumed by a yellow walleye.

Mortalities or die-offs of trout-perch are occasionally reported after spawning. One such mortality was observed in late May, 1960, in Lake Mindemoya, Manitoulin Island, Ont. The mortality was considered to have been caused by a protozoan infection *Myxoboliosis* (A. M. McCombie, personal communication).

Relation to man The trout-perch is probably of little direct importance except when used occasionally as bait but it is of very great importance as a forage fish for a wide range of predator species. Since it moves into shallows of lakes to feed in evening, and back into deeper water at the approach of dawn, it probably serves an important role as a nutrient transporter as noted by McPhail and Lindsey (1970).

The facts that it has large eggs and that lake populations have a prolonged spawning period, suggest that it might be a useful laboratory species where eggs are required, and indeed it has been used in a limited way for such studies.

Nomenclature

Salmo Omisco Maycus — Walbaum 1792: 65 (type locality Hudson Bay)
Percopsis guttatus — Agassiz 1850: 286
Salmoperca pellucida — Thompson 1853: 33
Percopsis omiscomaycus (Walbaum) — Kendall 1911: 51
Percopsis omisco-maycus Walbaum — Hubbs 1926: 54

Etymology *Percopsis* — perch like; *omiscomaycus* — probably an Algonkian Indian name that includes the root "trout" (McPhail and Lindsey).

Common names Trout-perch, silver chub, troutperch. French common name: *omisco.*

Suggested Reading — Percopsidae

KINNEY, E. C. MS 1950. The life-history of the trout perch, *Percopsis omiscomaycus* (Walbaum), in western Lake Erie. M.Sc. Thesis. Ohio State Univ., Columbus, Ohio. 75 p.

LAWLER, G. H. 1954. Observations on the trout-perch *Percopsis omiscomaycus* (Walbaum), at Heming Lake, Manitoba. J. Fish. Res. Bd. Canada 11: 1–4.

MAGNUSON, J. L., and L. L. SMITH. 1963. Some phases of the life history of the trout-perch. Ecology 44: 83–95.

THE PERCH-LIKE FISHES — Order Perciformes (Percomorphi)

Spiny-rayed fishes of exceedingly variable size and shape, many conspicuously compressed laterally; the body shapes of perches, sunfishes, and mackerels are characteristic. Skull elongate, strongly ossified; jaws strong, usually with well-developed teeth; upper jaw bordered by premaxillae; post-temporal usually forked, articulating with skull; orbitosphenoid and hypocoracoid absent. Gill rakers usually stubby and toothed. Branchiostegal rays 4–7. Fins with pungent spines; dorsal fins usually 2, first dorsal spiny, second dorsal soft rayed; caudal with 17 principal rays (15 branched) or fewer; soft-rayed anal preceded by 2 or 3 spines; pelvics, when present, thoracic or jugular, of 1 spine and 5 or fewer soft rays; the pelvic girdle usually attached to cleithra; pectoral fin position elevated on side, the base more or less vertically oriented. Scales ctenoid, sometimes cycloid, or variously modified. Physoclists., Vertebrae 24 or more.

The perciforms are widely distributed in tropical and subtropical waters, and less abundantly in temperate seas throughout the world; they have also successfully invaded fresh waters of all continents except Australia. This is the largest order of fishes, containing at least 135 families and over 6000 species; represented in Canadian fresh waters by 4 families and 28 species. Upper Cretaceous to Recent.

TEMPERATE BASS FAMILY — Percichthyidae

These are laterally compressed, deep-bodied, percoid fishes, with the skull somewhat elevated and strongly ossified and with lateral canals of head at least partially enclosed in bone; jaws well developed, armed with numerous teeth; maxillary expanded posteriorly. Branchiostegal rays 7. Spiny and soft-rayed dorsal fins usually distinct or only slightly joined at base. Pelvic fins thoracic, of 1 spine and 5 soft rays, no axillary process, or scaly process, in axil of pelvic fin. Scales ctenoid; lateral line well developed and complete. Vertebrae 24.

The fishes included in this family were formerly considered to form a part of the family Serranidae, a large and poorly defined group of fishes referred to as the sea basses. Gosline (1966) attempted to provide a more rational grouping for the serranids and proposed expansion of the family Percichthyidae to include the genus *Morone (=Roccus).* Three species occur in Canadian fresh waters.

Key to Species

1 Dorsal fins slightly joined at base by membrane; soft anal rays 8–10, usually 9; anal spines stout, not graduated in length, second and third spines subequal; no teeth on base of tongue; no lateral stripes. .... WHITE PERCH, *Morone americana* (p. 684)

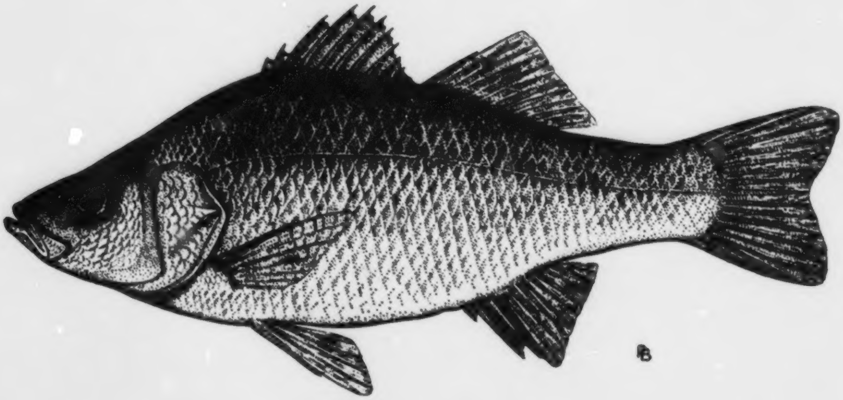
Dorsal fins entirely separated at base; soft anal rays 9–13; anal spines graduated in length, fine teeth at base of tongue; 4–7 lateral stripes 2

2 Soft anal rays 12 or 13; anal spines slender, the longest spine equal to or greater than one-half height of fin. .... WHITE BASS, *Morone chrysops* (p. 689)

Soft anal rays 9–11; anal spines more slender, longest spine less than one-half height of fin. .... STRIPED BASS, *Morone saxatilis* (p. 693)

WHITE PERCH

Morone americana (Gmelin)



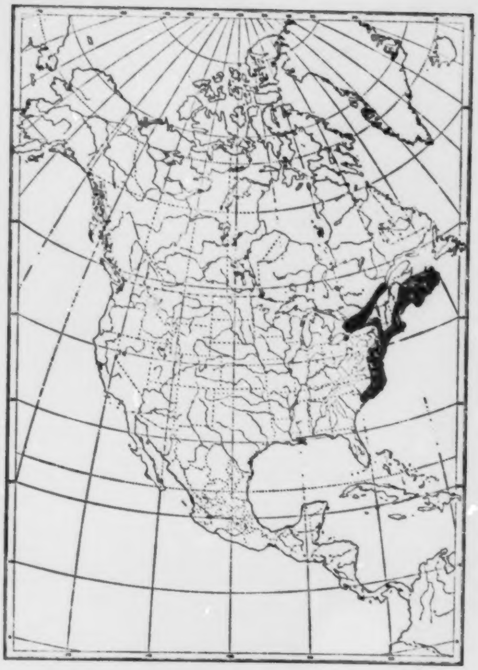
Description Body deep, usually 5–7 inches (127–178 mm) long, compressed laterally, sloping steeply from eye to dorsal origin, distinctly heaviest anteriorly, deepest near origin of spinous dorsal fin, its depth 24.4–29.0% of total length. Head large, triangular, its length 26.3–29.7% of total length; eye diameter 18.9–28.6% of head length; snout moderate, 28.6–30.9% of head length; interorbital 24.5–27.9%. of head length; mouth moderately large, gape extending to below eye, jaws about equal; teeth in jaws and vomer small, sharp, and numerous; no teeth on base of tongue but a band of small teeth around distal periphery of tongue. Gill rakers 19–22. Branchiostegal rays 7. Fins: dorsals 2, combined base of both fins long, 32.4–37.5% of total length, first dorsal spiny, 9 spines, weakly joined to anterior part of second dorsal by membrane, second dorsal of 1 spine and 11 or 12 branched rays; caudal weakly forked, rays 17 (15 branched); anal of 3 spines and 8–10 branched rays, usually 9; pelvics thoracic, 1 spine and 5 branched rays; pectorals somewhat rounded, rays 15. Scales large, ctenoid, 46–51 in lateral line, on opercles, cheeks, and interorbital. Vertebrae 24.

Colour The colour of the white perch is variable, from olivaceous, dark greyish green, dark silvery grey, or dark brown to almost black on the dorsal surface, becoming paler olive or silvery green on the sides, and silvery white on the belly. In fresh water the colour is quite dark and less silvery. There is a bluish lustre on the head and lower jaw of spawning adults. The fins are generally dusky, the pectoral fin lightest. Pelvic and anal fins occasionally have a rosy tint.

Systematic notes The current name is employed because of the revision of this group by Whitehead and Wheeler (1967) who selected the generic name *Morone*.

Distribution The white perch is distributed, usually in brackish waters, along the Atlantic coast of North America from the upper St. Lawrence River and southern Gulf of St. Lawrence to South Carolina. It is abundant in the Chesapeake Bay region. In fresh water it inhabits ponds and lakes close to the sea, especially in the northern part of its range. It is a common species in the Hudson River below Albany, and in many lakes in the lower Hudson River drainage. Larsen (1954) reported the capture of 3 specimens in the Pennsylvania waters of Lake Erie but no further captures in Lake Erie have been reported.

In Canada the white perch is found in Prince Edward Island, Nova Scotia, and New Brunswick (rare in Gulf of St. Lawrence region), and recently was reported from the vicinity of Quebec City and Montreal in the St. Lawrence River (Vladykov 1952). It is a relative newcomer to Ontario, is now resident throughout Lake Ontario, and is the dominant species in the Bay of Quinte region. Populations are also present in the lower Niagara River and in the Welland Canal.



In their discussion of the invasion of the lower Great Lakes by the white perch, Scott and Christie (1963) stated that "available evidence suggests that the white perch gained access to Lake Ontario via the Oswego River, as a result of movement by the Hudson River populations northward and westward through the Mohawk River Valley and Erie Barge Canal," and they suggested it is inevitable that this species will become established in Lake Erie.

Biology The white perch spawns in the spring. Studies of Bay of Quinte, Lake Ontario populations by Sheri and Power

(1968) indicated that spawning commences about mid-May and may extend to the end of June. During this period water temperatures are in the range of 51.8°–59.0° F (11°–15° C). Details such as site selected, dates, and time of day, etc., of spawning seem not to have been recorded for white perch populations in the Maritime Provinces nor in Quebec. This is particularly true of anadromous populations. However, collections by the authors in North Lake of the Upper St. Croix River watershed in New Brunswick, indicate that a large number of adults were spawning in shallow (0–12 feet, 0–3.7 m) water, May 25–27, 1958. In nearby Maine spawning is said to occur mainly in June but may extend from May 27 to July 22 (Foster 1918) at temperatures around 59°–60° F (15.0°–15.6° C). No information is available on the time of spawning of anadromous populations in Canadian waters, but in the Chesapeake Bay region spawning occurs in April and early May.

For most populations reported in the literature, spawning is prolonged and continues for 1–2 weeks and does not take place all at once. Foster (1918) and Mansueti (1961) noted that only a portion of the total number of eggs in the ovaries of an individual are released at one time, and suggested that the eggs ripen progressively and may be released during two or three separate spawning acts. Foster estimated that only 10% of the eggs of spawners were ripe at the height of the season.

Spawning takes place in shallow water and is said to occur over any and every bottom type with little evidence of preference. Large numbers of adult fish mill about in shallow water, the females and males seeming to release their eggs and sperm, more or less randomly. The eggs are rather small, 0.79 mm in diameter before fertilization and 0.92 mm after fertilization. A. N. Sheri (unpublished information) obtained a range of 0.55–0.70 mm for egg diameters of eggs removed from ovaries of white perch caught in Bay of Quinte. The eggs are adhesive and become attached to vegetation, rocks, and other bottom objects. The total number of eggs have been shown to vary from 20,000 to over 300,000 depending, in part at least, on the size of the female; this is a large number of eggs for such a relatively small fish. Many texts describing U.S. populations quote figures of 50,000–150,000 eggs per female, some as high as 321,000, but Sheri and Power (1968), in a study of 50 specimens of the rather recently established Lake Ontario (Bay of Quinte) populations, provide the only known figures for Canadian waters. Number of eggs for various size groups of females, using data selected from Sheri and Power (1968), are as follows:

No. fish	FL (*mm*)	No. of Eggs	
		Range	Mean
4	151–160	15,740–26,770	21,180
14	171–180	18,598–61,488	36,687
3	201–210	91,448–98,556	95,752
2	241–250	221,003–247,681	234,342

These authors noted that they sampled the population before spawning ("the fish were about to spawn when collected, . . ." p. 2225) and hence possibly avoided the problems in variation involved in sampling specimens that had already released some of their total complement of eggs, although they did remark on the wide variation in egg number in fish of similar size and age. Fecundity of white perch is of considerable interest because of the proven ability of this species to dominate quickly a favourable habitat despite the presence of other established species, as was demonstrated in Lake Ontario. However, because of the propensity to increase in number rapidly, white perch tend to become over-populated and large populations of stunted or dwarfed individuals result.

The small eggs hatch in 4–4½ days at the expected spawning temperature of 59° F (15° C) but at higher temperatures hatching time is decreased and eggs will hatch in about 30 hours at 68° F (20° C). Thoits (1958) noted that the embryology of the white perch has not received attention and this situation has apparently not changed. He noted that young white perch are 2.3 mm long on hatching and grow rapidly, reaching 1.5–2.5 inches (40–65 mm) in length by July and August.

Growth rates of white perch vary widely depending on the region and also on the state of the population under study. Old landlocked populations in small oligotrophic lakes in the Atlantic coastal region will possibly have a slower rate of growth than newly expanding populations, such as those in Lake Ontario.

The annulus of Lake Ontario (Bay of Quinte) white perch is formed rather late in the year, usually in July, according to Sheri and Power (1969a). Mansueti (1960) demonstrated that the most satisfactory place on the body to take scale samples is the area under the posterior two-thirds of the base of the dorsal fin, above and below the lateral line.

Comparative growth rates of white perch are presented in the following table. In general, females average slightly larger than males after the second year and the percentage of females to males tends to increase with age, suggesting that males have a higher mortality rate than females.

The average life span for most populations seems to be 5–7 years. The oldest white perch reported was 17 years old, caught in Maine (Cooper 1941), and Raney (1965) mentioned a New York specimen that was 15 years old. Large-sized white perch are not well recorded in Canada since the white perch is only a marginal sport fish. However, Mr W. J. Christie informed us that the largest fish caught in Bay of Quinte waters was a female, 12 years old, caught in the fall of 1969; it was 13.2 inches (335 mm) long and weighed 1.72 pounds (780 g). Raney (1965) stated the maximum size in estuaries and large rivers approached 6 pounds but provided no evidence. For U.S. waters Thoits (1958) noted that fish up to 3 pounds have been caught in Quabbin Reservoir, Massachusetts, and Carlander (1953) listed a 4.75-pound fish, 19 inches long, caught in Maine.

White perch thrive in a variety of habitats but seem to be more successful in waters that reach 75.2° F (24° C) or more in summer. Although good production is achieved by anadromous populations along the Atlantic seaboard of the northern United States, particularly in the Chesapeake Bay region, sea-run populations in the Maritime Provinces are not common and consist of small fish where they do occur. There are virtually no anadromous stocks in the Bay of Fundy, possibly because of the low temperatures. However, in the La Have River, N.S., a seaward migration in summer has been reported by provincial fishery survey workers.

White perch have generally been observed to move onshore at night and offshore into deeper water at dawn.

A vertical diel movement of migration was tested by Sheri and Power (1969b) who demonstrated a movement toward the surface at night and withdrawal to deeper water during daylight hours. At times very dense schools may be formed. This movement is apparently associated, in part at least, with feeding.

The white perch is a well-adapted predaceous species. Young white perch consume microplankton; as they grow larger, aquatic insect larvae become a significant part of the diet, whereas large white perch

	L. Jesse, N.S. (Smith 1939)		L. Ontario (Sheri 1968)	Oneida L., N.Y. (Alsop and Forney 1962)	
Age	Observed FL	Observed Wt	Calculated FL	Calculated TL	
	(cm)	*(g)*	*(cm)*	*(inches)*	*(cm)*
1	9.1	9.1	7.9	3.49	8.9
2	11.0	17.2	12.6	7.46	19.0
3	12.7	25.1	16.2	8.86	22.6
4	13.8	32.7	18.6	9.59	24.4
5	15.5	47.1	20.6	10.12	25.7
6	–	–	22.1	10.58	26.9
7	–	–	23.9	12.10	30.7
8	–	–	25.9	–	–
9	–	–	27.3	–	–

consume a high percentage of fishes including young of their own species.

A study of the summer food and feeding habits of the Lake Ontario (Bay of Quinte) populations was carried out by Leach (1962) in 1959, 1960, and 1961. His studies indicated that there were two peak feeding periods daily — noon, and about midnight, the latter being the more important — but there were indications that sporadic feeding sometimes took place in the intervals. The importance of evening feeding was also noted by Webster (1943) for a Connecticut population, but the time was earlier — up to 8:30 PM.

The principal foods consumed in the Bay of Quinte were insect larvae and fishes whereas invertebrates such as crustaceans, molluscs, and oligochaetes made up less than 10%. Dipterous larvae, especially chironomids, were significantly more important than any other insect types, and the fishes consumed were yellow perch, white perch, and johnny darters. Fish became an increasingly important food item of larger white perch, constituting about 35% of the diet of 7-inch (178-mm) fish, and 70% of the diet of 8.5–10-inch (216–254-mm) ones. In a study of food of white perch in relation to supply in Tedford Lake, N.S., Smith (1947) stated that pelagic and bottom-haunting microcrustaceans were found in white perch up to 5.9 inches (150 mm), the pelagic species eaten "to the greatest extent by the smaller fish, the latter in increasing numbers as the size of the fish increased to 15.0 cm," and he stated further that above this size microcrustaceans were not eaten. Smith found that only white perch over 4 inches (110 mm) had eaten other fishes of small size (killifish, yellow perch, and occasionally a stickleback). A detailed list of the organisms eaten is presented by Smith. In a study of Maine white perch, Cooper (1941) also emphasized the importance of insect larvae and noted that smelt, yellow perch, and white perch were the fishes most often consumed.

The diet of salt water populations appears to have received scant attention, although Goode (1903) wrote the following in reference to U.S. populations: "They feed greedily on the spawn of other fish, particularly that of the shad; on insects, crabs, minnows and on the migratory schools of young eels ...."

Studies involving food of game fishes in Maine waters (Cooper 1941) indicated that young white perch provide forage for predator species; but Thoits (1958) noted that data in the files of the Massachusetts Division of Fisheries and Game revealed little evidence of use there by game fish such as smallmouth and largemouth bass, or chain pickerel. Leach (1962) stated that in the Bay of Quinte region of Lake Ontario, white perch were seldom preyed upon by other species (except white perch).

Thoits (1958) concurred with other workers that the white perch is only lightly affected by parasites. However lightly infected they may be, the list of known parasites is long for Maine, Massachusetts, and Connecticut specimens and includes leeches, copepods, glochidia (of molluscs), acanthocephalans, trematodes, cestodes, and nematodes (*see* Thoits for further details).

Studies on white perch in the Bay of Quinte region reveal that this species is not heavily infested by parasites or disease organisms (Dechtiar, personal communication).

Hoffman (1967) also listed parasites infecting this species in North American waters.

Relation to man The white perch is a good food fish and the white flaky flesh is highly regarded, especially in the eastern United States. Canadian white perch are equally delicious as we can personally attest, but unfortunately they seldom attain a size in Canadian waters large enough to attract anglers.

Along the U.S. Atlantic coast it is relatively abundant and is fished commercially, especially in the Chesapeake Bay region.

Because of the abundance of this species in certain areas, particularly in the Bay of Quinte region of Lake Ontario, the competition with game fishes for food could be a serious problem. Although the white perch is an excellent pan fish, there is no established fishery in Canada except in the Bay of Quinte and, since the species is not often exploited as a game fish, the result is that the populations continue to increase. Where over-population in fresh water occurs, the species tends to become stunted and, is undesirable, largely because of its adverse effect on more desirable species by competition, if not direct predation.

Nomenclature

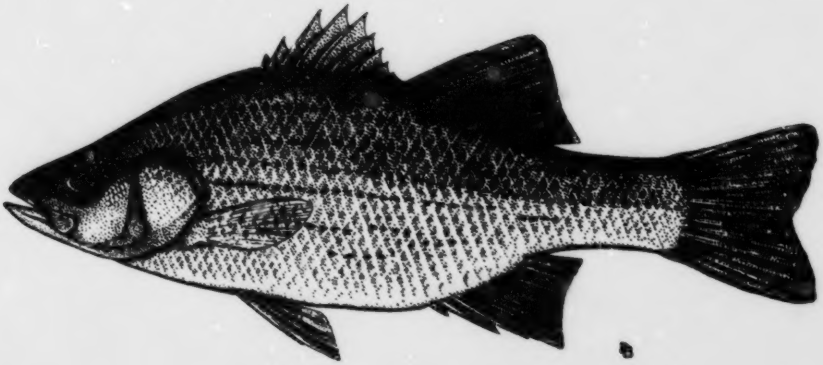
Perca americana	— Gmelin 1788: 1308 (type locality New York)
Labrax pallidus	— Perley 1852: 182
Morone Americana Gill	— Adams 1873: 304
Roccus americanus	— Jordan and Gilbert 1883a: 530
Morone	— Whitehead and Wheeler 1967: 23

Etymology *Morone* — (etymology unknown); *americana* — American.

Common names White perch, narrow-mouthed bass, silver perch, perch, bass, sea perch, gatte, "little white basse." French common name: *bar-perche*.

WHITE BASS

Morone chrysops (Rafinesque)



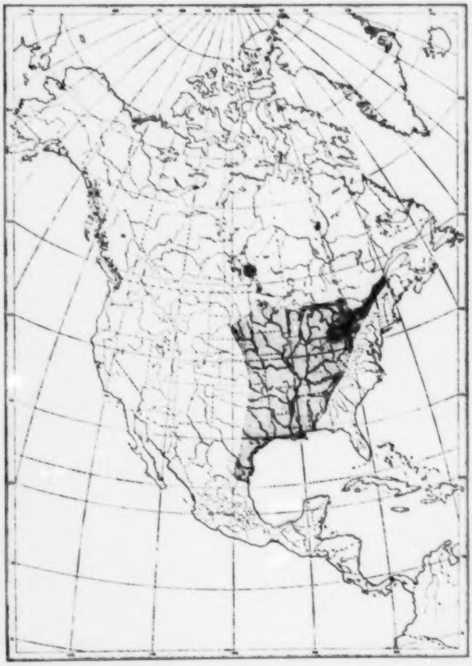
Description Body robust, usually 10–12 inches (254–305 mm) in total length, deep, compressed laterally, greatest depth mid-dorsally rather than at dorsal origin as for *M. americana*, body depth 24.8–26.8% of total length. Head triangular, smaller than in *M. americana*, its length 24.5—27.3% of total length; eye diameter 21.4—26.5% of head length; snout length 25.0–29.4% of head length; interorbital 21.2–27.8% of head length; mouth moderate, maxillary extending to middle of eye or beyond, lower jaw slightly protruding; teeth in jaws and vomer small, sharp, and in many rows, a single patch of teeth on anterior surface of tongue. Gill rakers 23–25. Branchiostegal rays 7. Fins: dorsals 2, combined base of both fins 31.7–35.2% of total length, first dorsal spiny, 9 spines, entirely separate from second dorsal, second dorsal of 1 spine and 12–14 branched rays; caudal distinctly forked, rays 17 (15 branched); anal of 3 spines and 12 or 13 branched rays; pelvics thoracic, 1 spine and 5 branched rays; pectorals somewhat pointed, rays 15–17. Scales large, ctenoid, 52–60 in lateral line, on opercles, cheeks, and interorbital. Vertebrae 24.

Colour Less variable than the white perch. Overall colouration silvery. The back is dark green or grey, shading to silvery on the sides, becoming white below. The sides have 5–7 horizontal dark stripes. The eye is tinted with yellow.

Systematic notes The current name is employed because of the revision of this group by Whitehead and Wheeler (1967) who selected the generic name *Morone*.

Distribution The white bass ranges from the St. Lawrence River west through the Great Lakes to Lake Huron. South, it occurs in most of the Great Lakes states from New York to Minnesota, westward to South Dakota and south in the Ohio and Mississippi valleys to the Gulf of Mexico. Its range in the United States has been greatly increased by transplanting.

In Canada the white bass has long been known to occur in Lake Ontario, Lake Erie, Detroit River, Lake St. Clair, Lake Huron, and Lake Nipissing. It apparently has recently extended its range into the Quebec waters of the St. Lawrence River and was first captured at Saint-Vallier, 20 miles east of Quebec City, in June 1944. In 1963 a specimen of white bass was caught in Lake Winnipeg, the first capture of the species for Manitoba waters. It is presumed access was gained via the Red River from North Dakota.



In Canada white bass have traditionally attained greatest abundance in Lake Erie.

Biology Studies of the biology of the white bass, including time and place of spawning, have not been conducted by Canadian biologists or, if so, have not been published, but the results of a number of studies in U.S. waters are available and have been the source for much of the information that follows. Unfortunately most of these studies relate to rate of growth and food, few to reproductive behaviour.

The white bass spawns in spring, like its close relatives the white perch and striped bass.

Sexually mature fish form schools, often unisexual schools, and move onto shoals or into estuaries for spawning, these inshore movements usually occurring when water temperature rises to 55°–60° F (12.8°–15.6° C). Precise dates of spawning undoubtedly vary slightly from season to season but in Lake Erie spawning usually takes place in May, at temperatures of 58°–70° F (14.4°–21.1° C), extending into June in cool years. In Lake Nipissing spawning probably takes place in late June. Riggs (1955) presented comparative data for spawning times in various parts of the United States, indicating that spawning may commence in April in southern states, in late May or June in northern ones.

The actual spawning act takes place in daylight (but has been reported to occur at night also), usually nearer the surface than the bottom and, within a population, may last for 5–10 days. The eggs are released near the surface or in midwater, both eggs and sperm are released simultaneously, the eggs becoming fertilized as they sink. The eggs measure about 0.8 mm, are heavy and adhesive, and on sinking, become attached to gravel, boulders, or vegetation on the bottom. Riggs (1955) reported that the number of eggs varied from 242,000 to 933,000 and averaged 565,000. The number of eggs presumably varies directly with the size of the female.

No parental care is given eggs or young; after spawning is completed the adults move offshore and over deeper water but usually remain near the surface. During this movement they may form schools, for schooling is characteristic of white bass both before and after spawning and even before attaining sexual maturity.

Eggs are said to hatch in 46 hours at 60° F (15.6° C). Fish (1932) reported the capture of larvae, 3.7–13.5 mm long, in western Lake Erie on June 29, 1929. She also figured and described larvae to a length of 18.5 mm. Growth is rapid and young white bass may attain total lengths of 5–6 inches (127–162 mm) by the fall of their first year. Van Oosten (1942) demonstrated that maximum growth occurred in the first year. The following calculated age–length relations are taken from Van Oosten (1942) and apply to fish caught in Lake Erie in 1927, 1928, and 1929 when conditions were markedly different than they are today. For comparison, figures are shown for rate of growth in Oneida Lake, N.Y., using 1948 through 1960 year-classes (Forney and Taylor 1963).

Year	Lake Erie calculated TL & Wt at end of year of life				Oneida Lake, N.Y. calculated TL at end of annulus	
	(inches)	*(mm)*	*(oz)*	*(g)*	*(inches)*	*(mm)*
1	4.7	119	0.7	20	5.3	135
2	8.2	208	3.8	108	10.3	262
3	10.9	277	9.4	266	12.3	312
4	12.4	315	14.1	401	13.3	338
5	13.2	335	17.1	486	14.0	356
6	13.6	345	18.8	533	14.7	373
7	14.0	356	20.3	577	15.4	391
8	–	–	–	–	16.0	406
9	–	–	–	–	17.4	442

Forney and Taylor noted that the growth of females is more rapid than that of males but the difference was slight. Van Oosten's data also demonstrated that females were slightly larger than males of the same age, but he did not consider the difference to be significant.

The greatest increment in weight in the Lake Erie study occurred in the third year. On the basis of this and the attainment of sexual maturity Van Oosten stressed that the legal-size limit should be 11 inches (279 mm). The majority of the Lake Erie white bass studied by Van Oosten did not mature sexually until age 3 when they averaged 10.9 inches (277 mm) total length. This species does not live as long as the white perch and seldom lives beyond 7 years. The scales, incidentally, usually show well-marked annuli and are easy to read.

White bass in Ontario waters average from ¾ to 1½ pounds. We have seen 3-pound bass from Lake Nipissing, but documented size records for Canadian caught fish over 2 pounds are rare.

The world record is said to be 5 pounds 4 ounces. A female weighing 4 pounds 6 ounces (1985 g) was caught in an Oklahoma impoundment in 1950 and a 4-pound 9-ounce (2070-g) fish caught in Arkansas in 1967 was considered to be a new state record.

White bass appear to prefer clear water rather than turbid or silty conditions. Indeed, there is experimental evidence suggesting that they are visual feeders (Greene 1962) and are not attracted to their prey by scent, hence, low turbidity levels may be essential for their survival. The schooling tendency is also sight dependent. They tend to occupy the upper water layers or epilimnion, usually to a depth of about 20 feet. Tagging and marking experiments in U.S. waters suggest that they may move considerable distances, up to 6.9 miles in a day.

White bass are carnivorous. The younger, smaller fish feed on microscopic crustaceans, insect larvae, and fishes; but fishes, especially yellow perch, become increasingly important in the diet with increase in size. Food studies of adult white bass in Iowa lakes indicate that fish (yellow perch, bluegills, carp, black crappies) constitute two-thirds of the total volume, the remainder consisting of aquatic insects, especially mayflies, and crustaceans. Similar studies in Oneida Lake, N.Y., by Forney and Taylor (1963) also showed fish, especially yellow perch, and aquatic insects (principally mayflies, chironomids in fall) to be primary food items. Small gizzard shad may dominate in the diet, as demonstrated by Bonn (1953) for Lake Texoma, Texas. Cyprinids or minnows may also form a significant portion of the diet.

Bangham (1955) examined three white bass from South Bay, Lake Huron, for parasites and reported a number of trematodes, nematodes, cestodes, and a species of acanthocephalan. Bangham and Hunter (1939) reported that many adults of the cestode tapeworm *Bothriocephalus cuspidatus* were found in one fish, but only larvae in seven others. Hoffman (1967) listed additional parasites found in white bass.

Relation to man The white bass is an important game fish in many parts of the central U.S., especially in the Great Lakes drainage, but is of less importance in Canada because of its more restricted distribution. At times, however, it may provide excellent sport fishing, especially in Lake Nipissing and in river mouths along the northern shore of Lake Ontario, especially in spring when the schools move into inshore waters. At such times spinning with streamer flies can be most effective, and catches of 2 or 3 dozen fish in an hour were not uncommon in the 1950's. In Lake Erie the white bass has supported, at times, a small but important fishery, as the following figures indicate:

	Catch (*lb*)	
Year	Lake Erie	Total for Ontario
1964	1,722,000	1,836,208
1965	2,610,948	2,733,247
1966	1,756,888	1,805,932
1967	822,000	857,000
1968	819,495	819,495

Nomenclature

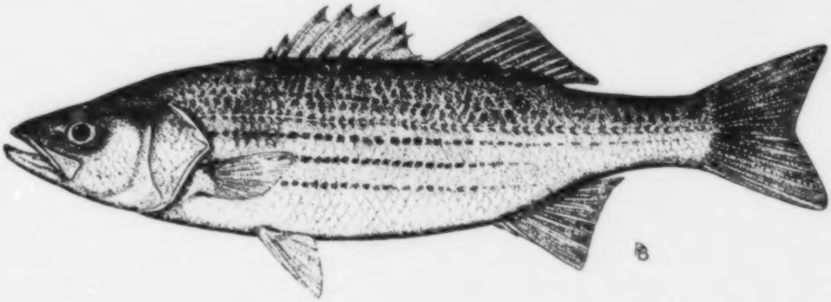
Perca chrysops	— Rafinesque 1820a: 370 (type locality Falls of Ohio)
Labrax notatus (Smith)	— Richardson 1836: 8
Labrax albidus	— Cox 1896b: 71
Labrax osculatii Filippi	— Jordan and Evermann 1896–1900: 1132
Lepibema chrysops Rafinesque	— Hubbs 1926: 55
Morone	— Whitehead and Wheeler 1967: 23
Roccus chrysops (Rafinesque)	— Scott and Crossman 1969: 22

Etymology *Morone* — (etymology unknown); *chrysops* — gold; eye.

Common names White bass, silver bass, white lake-bass. French common name: *bar blanc*.

STRIPED BASS

Morone saxatilis (Walbaum)

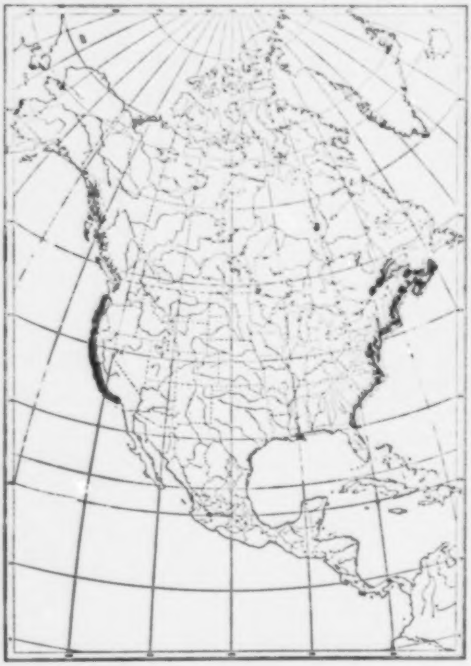


Description Body elongate, usually 16–18 inches (406–457 mm) in length, compressed laterally, depth greatest below posterior portion of spinous dorsal fin, its depth 21.3–24.2% of total length. Head large, triangular, its length 24.5–27.4% of total length; eye large, its diameter 15.7–22.9% of head length; snout long, 29.4–31.4% of head length; interorbital 22.1–26.7% of head length; mouth large, maxillary extending to middle of eye or beyond, lower jaw distinctly protruding; teeth in jaws and vomer small, sharp, and numerous, 2 elongate patches of teeth on each side of tongue. Gill rakers 21–26 (Canadian range — Lewis 1957), 20–29 over whole range. Branchiostegal rays 7. Fins: dorsals 2, entirely separated, combined base of both fins 30.9–36.4% of total length, first dorsal spiny, 9 spines (over whole range 7–12), second dorsal of 1 spine and 12 branched rays (over whole range 8–14); caudal distinctly forked, rays 17 (15 branched); anal of 3 spines, graduated, the third and longest less than one-half longest branched ray, and 9–11 branched rays (over whole range 7–12); pelvics small, thoracic, 1 spine and 5 branched rays; pectorals small, narrow, somewhat pointed, of 31–34 branched rays (over whole range 28–37). Scales large, ctenoid, 58–64 (Canadian range only) in lateral line, on opercles and cheeks. Vertebrae 24 (excluding urostylar vertebra).

Colour The striped bass is dark olive-green (rarely pale green) to steel-blue or black above, paling on sides to silvery, sometimes with brassy reflections, becoming white on belly. There are 7 or 8 prominent, horizontal, dark stripes along the sides, more or less interrupted, following scale rows; usually 3 or 4 above lateral line, 1 along lateral line, and 3 below it; the 2 above, the stripe on the lateral line, and the 1 below are generally longest, extending almost to caudal base, lowest stripe ending before anal fin. All stripes except lowest are above level of pectoral fins. No stripes extend onto the head. Young striped bass 2.4–2.8 inches (60–70 mm) do not usually have the longitudinal stripes; fish 2.0–3.2 inches (50–80 mm) often have 6–10 dusky, vertical crossbars.

Systematic notes The current name is employed because of the revision of this group by Whitehead and Wheeler (1967) who selected the generic name *Morone*. The distinctness or integrity of populations along the Atlantic seaboard have been studied by many biologists (Vladykov and Wallace 1952; Raney and deSylva 1953; Raney et al. 1954; Raney 1957; Lund 1957;

Lewis 1957) using meristic and morphometric characters. The results suggest that discrete populations exist in some regions, such as the Hudson River, but that Chesapeake Bay may contain as many as four populations during the overwintering period. Studies of body depth and caudal peduncle depth values suggested the existence of north–south clinal variations. The St. Lawrence River population was considered to be distinctive but is now seriously depleted.



Distribution The striped bass is a coastal species, seldom found more than a few miles from shore except during spring and fall migrations. It is distributed along the North American Atlantic coast from the St. Lawrence River to the St. Johns River in northern Florida, and is found in the Gulf of Mexico, in fresh and brackish tributaries in western Florida, Alabama, Mississippi, and Louisiana.

Introduced on the Pacific coast of North America in 1879 and 1882, it occurs from the Columbia River, Oregon, to southern California.

In Canada the striped bass occurs in the coastal waters of the Maritime Provinces. It has been reported from Malpeque Bay, Tignish, and Summerside, P.E.I.; Cheticamp, River Philip, Canso, Mira Bay, Chedabucto Bay, Mahone Bay, the Minas Basin area of the Bay of Fundy, the shores of Yarmouth County, Shubenacadie and Annapolis rivers, and Shubenacadie and Grand lakes, N.S.; in New Brunswick, primarily restricted to fresh water, it is found in the Richibucto River, Miramichi River and estuary, Tabusintac, Tracadie, and Pokemouche rivers, in the Saint John River watershed in the Aroostook River, below Beechwood Dam, in the Fredericton area in Grand Lake, Long Reach (Oak Point area), Nerepis, Hammond, and Kennebecasis rivers, Grand Bay, and at the Reversing Falls. Scott and Crossman (1959) could find no record of its occurrence in the Nepisiguit or Restigouche rivers.

It occurs sparingly in the Gulf of St. Lawrence, and in the St. Lawrence River as far up as about Sorel. Cuerrier et al. (1946) reported that striped bass were caught in hoopnets at the entrance of Saint-François and Nicolet rivers, lac Saint-Pierre, in small quantities in the month of May.

It is not found north of the Laurentian Channel.

Attempts have been made to establish striped bass in a number of freshwater areas in the U.S. with limited success.

Biology Canadian populations of striped bass have not been studied with the intensity given to the species in the United States, probably because of its limited distribution in Canada and the great fluctuations in numbers in the regions that it does inhabit. St. Lawrence River populations have received more attention than those of Nova Scotia and New Brunswick but even the St. Lawrence River populations have stimulated the writing of relatively few scientific papers. Furthermore, these populations, which once supported a fishery, are now severely decimated. Nevertheless, the following information applied primarily to the following Canadian regions — the St. Lawrence River, the southern or southeastern coastal area of Nova Scotia, and the Bay of Fundy.

Throughout its range the striped bass spawns in fresh water. In the St. Lawrence River there is a fall migration upriver, the potential spawners spend the winter in the river, then swim up to their spawning grounds in the spring, usually spawning in June. Prespawning fish may travel long distances upriver, in fresh water. In former years some large fish have been taken as far inland as lac Saint-Pierre and a very few individuals have been caught at lac Saint-Louis at Montreal. In spring large, mature fish migrate up such rivers as the Saint John and Miramichi in New Brunswick, and the Shubenacadie and Annapolis rivers in Nova Scotia.

Although direct observations of spawning fish in these rivers seem not to be available, indirect evidence suggests that spawning occurs in early June. In some rivers spawning occurs just above the head of tide, but in most cases the ripe fish seem to move well into fresh water before spawning.

Fecundity of United States populations has received considerable attention. The average number of eggs per female is well documented and is more or less proportional to the weight. Raney (1952) cited records of egg numbers with weight of spawning females and noted that reports gave a range of 14,000 eggs for a 3-pound female to 3,220,000 eggs for a 50-pound female. Records from fish cultural work in North Carolina indicated that most fish yielded 180,000–700,000 eggs each. Although females spawn more than once, they do not necessarily spawn every year.

The eggs are relatively large, have a large oil globule, and measure 1.0–1.35 mm before extrusion, and about 3.6 mm a few hours after they are fertilized and have undergone swelling. The eggs are semibuoyant and may be swept along with the current. They hatch in 70–74 hours at 58°–60° F (14.4°–15.6° C) and in about 48 hours at 64°–67° F (17.8°–19.4° C). The development of the larvae at 120 hours (5.2 mm), 144 hours (5.8 mm), and 192 hours (6.0 mm) was illustrated and described by Pearson (1938). The early larval stages have also been described by Scofield and Coleman (1910). Raney (1952) provided a most useful review of works on the egg and larval stages. Leim (1924, p. 52) gave some figures on larval abundance in the Shubenacadie River, N.S., which flows into the Minas Basin "in 1922 three plankton tows yielded 516, 977, and 422 larvae of the striped bass, *Roccus lineatus*, which was practically the only fish which spawned in the Shubenacadie River at nearly the same time as the shad and whose larvae were found in greatest abundance near the head of the tidal zone."

We seem to know very little of the movements of young-of-the-year, and one- or two-year-old striped bass in Canadian waters. However, McKenzie (1959) noted that many young bass 2.7–5.5 inches (70–140 mm) were found in recent years (1945+) among the tomcod caught during the late autumn and early winter. McKenzie (personal communication) later elaborated on this statement, indicating that these small bass were taken formerly in considerable numbers in the Miramichi River between Loggieville and Newcastle in New Brunswick. Fishing in the river ceased in January. The size of these fish would suggest that they were young-of-the-year or possibly yearlings. After the first summer the young have been observed to form small schools (in Hudson River) and apparently prefer sand and gravel bottom and at least some current. The tendency to form schools is most characteristic and young bass of 2–3 pounds may migrate over great distances. In New Brunswick streams flowing into the Bay of Fundy, young bass can sometimes be seen entering the lower reaches of rivers with the incoming tide, rolling, and flashing at the surface and chasing all small fishes. They leave inconspicuously before ebb tide.

Growth is rapid during the first year or two. The only rate of growth figures for Canadian populations are those provided by Magnin and Beaulieu (1967) for St. Lawrence River populations. The 95% ranges for fork lengths calculated for the time of last annulus formation are as follows:

Age	FL (*mm*)
1	69–124
2	165–268
3	276–359
4	343–433
5	380–485
6	431–532
7	461–596
8	507–626
9	479–681

St. Lawrence River striped bass averaged 5–12 pounds (Vladykov 1947), and Raney (1952) quoted Vladykov (1949) as saying that the largest he had seen was 24 pounds and the largest taken by fishermen was 32 pounds. Vladykov and McKenzie (1935) reported that fish up to 50 pounds were caught in Grand Lake, N.S. Davidson (1949, 1950, 1951), however, made no mention of such large fish in her studies in Shubenacadie Lake in 1949–51. Most fish caught were of 3.0- to 4.5-pound size range, but a 15- to 18-pound fish was trapped in a pool and killed, and a 17.5-pound one was found dead in Shubenacadie River. Large runs and good angling catches of striped bass averaging 3–4 pounds were reported in tidal streams emptying into Bay of Fundy in July and August 1960. Similar runs were reported for Northumberland Strait and Prince Edward Island streams for the same year.

Raney (1952) gave a comprehensive review of sizes attained in various United States waters. Apparently the largest ever reported were caught in North Carolina in 1891 and several weighed 125 pounds each.

The striped bass is a voracious carnivore, consuming a variety of food including many kinds of living fishes, crustaceans, and other invertebrates such as annelid worms and insects.

Detailed studies of the food of the striped bass have been undertaken in the United States, and Merriman (1941), Raney (1952), and Hollis (1952) gave detailed accounts and summaries of the literature.

Larval striped bass feed on zooplankton. Young bass eat primarily small shrimps (*Gammarus* and *Crago*) and other crustaceans, annelid worms, and insects. LeCompte (1926), studying Atlantic coast populations, noted that marine worms composed 50% of the food, crustaceans and other marine species 48%, and small fish only 2%, that young bass begin feeding on small species of crustaceans and worms, and as they grow in size consume shrimp and young fish.

The diet of adult bass in rivers and lakes is principally of small fishes, such as herring, menhaden, smelt, alewives, shad, silversides, and mummichogs. Although shad is commonly reported as a food item of striped bass in rivers in the United States, it is noteworthy that Leim (1924) was unable to establish that striped bass up to 9.9 inches (250 mm) preyed upon young shad in Shubenacadie River, N.S. Davidson (1950), however, examined the stomachs of 32 striped bass in Shubenacadie Lake, N.S., and found that 13 were empty, 3 contained partly digested elvers, and the rest small fishes. She stated that American shad were the chief food during shad migration. Although anglers suspected that bass preyed on salmon, she could find no supporting evidence.

Along rocky, open shores striped bass prey upon crustaceans such as small crabs, shrimps, and lobsters.

Striped bass do not eat steadily, but appear to gorge themselves, then stop feeding until digestion is completed. Individuals in a school feed simultaneously. For a very short period before spawning, and during the actual spawning process, they cease to eat (Trent and Hassler 1966).

Unfortunately, there is little information available on the food of this species in Canadian waters where there is need of further study.

When small, striped bass may be preyed upon by any larger fishes with which they come in contact, such as tomcod and, later, cod, silver hake, and even larger striped bass. Adult striped bass, however, have few enemies except man — who, indeed, is enemy enough.

Although striped bass are attacked by various external and internal parasites, there is no evidence that their general well-being is seriously affected. Merriman (1941) and Raney (1952) provided summaries of parasites and diseases affecting striped bass in United States waters, but we have no information on this phase of the biology of the species in Canadian waters. Raney listed monogenetic and digenetic trematodes, cestodes, acanthocephalans, and a few records of ectoparasites, such as copepods, lernaeopodids, and ergasilids. Merriman also noted a high incidence of cataracts on the eyes of Connecticut specimens. *See also* Hoffman (1967) for additional information.

Relation to man Canadian populations of striped bass seem not to be highly valued, at least in comparison with their United States counterparts. It is of importance as a game and commercial fish when found in sufficient numbers. A commercial fishery in Nova Scotia yielded 15,000 pounds in 1963, but this declined in 1967 to landings of 4000 pounds (Fisheries Statistics of Canada, Nova Scotia 1967). In July and August, 1960–61, large runs and good angling catches were reported from the tidal streams emptying into the Bay of Fundy and along Yarmouth County, the fish averaging 3–4 pounds. The numbers of striped bass were reported to have increased in the Gulf of St. Lawrence areas around Prince Edward Island and in the Northumberland Strait during the same period. In earlier years (1964+) the striped bass was fished commercially, and also as a sport fishery, in the St. Lawrence River around Sorel, Que. However, St. Lawrence River stocks are now reported to be seriously depleted (V. Legendre, personal communication).

In New Brunswick, striped bass are caught in various rivers, including the Miramichi, but are not utilized by sportsmen and have little or no commercial significance.

In the United States it is an important game and commercial fish on both the Atlantic and Pacific coasts, and is highly valued as a food fish.

Nomenclature

Perca saxatilis	— Walbaum 1792: 330 (type locality New York)
Labrax notatus (Smith)	— Richardson 1836: 8
perca labrax	— Perley 1852: 22
Labrax Lineatus	— Perley 1852: 181
Labrax lineatus	— Fortin 1864: 60
Roccus lineatus	— Adams 1873: 248
Roccus Lineatus Gill	— Adams 1873: 304
Roccus lineatus (Bloch) Gill	— Cox 1896b: 70
Morone	— Whitehead and Wheeler 1967: 23
Roccus saxatilis (Walbaum)	— Scott and Crossman 1969: 22

Etymology *Morone* — (etymology unknown); *saxatilis* — living among rocks.

Common names Striped bass, striper bass, rockfish. French common name: *bar rayé*.

Suggested Reading — Percichthyidae

Alsop, R. G., and J. L. Forney. 1962. Growth and food of white perch in Oneida Lake. N.Y. Fish Game J. 9(2): 133–136.

Beaulieu, G. 1962. Résultats d'étiquetage du bar d'Amérique dans le fleuve Saint-Laurent de 1945 à 1960. Natur. Can. 89(8–9): 217–236.

Forney, J. L., and **C. B. Taylor**. 1963. Age and growth of white bass in Oneida Lake, New York. N.Y. Fish Game J. 10(2): 194–200.

Leim, A. H., and **W. B. Scott**. 1966. Fishes of the Atlantic coast of Canada. Fish. Res. Board Can. Bull. 155: 485 p.

Magnin, É., et **G. Beaulieu**. 1967. Le bar, *Roccus saxatilis* (Walbaum), du Fleuve Saint-Laurent. Natur. Can. 94: 539–555.

Mansueti, R. J. 1961. Movements, reproduction, and mortality of the white perch, *Roccus americanus*, in the Patuxent estuary, Maryland. Chesapeake Sci. 2(3–4): 142–205.

Massman, W. H. 1967. A bibliography of the striped bass. Sport Fishing Institute, Washington. 15 p.

Merriman, D. 1937. Notes on the life history of the striped bass *(Roccus lineatus)*. Copeia 1937(1): 15–37.

1941. Studies on the striped bass *(Roccus saxatilis)* of the Atlantic coast. U.S. Fish Wildlife Serv. Fish. Bull. 35, vol. 50: 1–77.

Nichols, P. R. 1966. The striped bass. U.S. Fish Wildlife Serv. Fish. Leafl. 592: 6 p.

Raney, E. C. 1952. The life history of the striped bass, *Roccus saxatilis* (Walbaum). Bull. Bingham Oceanogr. Collect. 14(1): 5–97.

1965. Some pan fishes of New York. Inform. leafl. N.Y. State Conserv. Dep. Div. Conserv. Educ. Apr–May. 16 p.

Raney, E. C., W. S. Woolcott, and **A. G. Mehring**. 1954. Migratory pattern and racial structure of Atlantic coast striped bass. Trans. Nineteenth N. Amer. Wildlife Conf. 376–396.

Riggs, C. D. 1955. Reproduction of the white bass, *Morone chrysops*. Invest. Indiana Lakes Streams 4(3): 87–110.

Scott, W. B., and **W. J. Christie**. 1963. The invasion of the lower Great Lakes by the white perch, *Roccus americanus* (Gmelin). J. Fish. Res. Bd. Canada 20(5): 1189–1195.

Sheri, A. N. MS 1968. Growth dynamics of white perch, *Roccus americanus*, during colonization of Bay of Quinte, Lake Ontario. Ph.D. Thesis. Univ. Waterloo, Waterloo, Ont.

Sigler, W. F. 1949. Life history of the white bass, *Lepibema chrysops* (Rafinesque), of Spirit Lake, Iowa. Iowa State College Agr. Mech. Arts Res. Bull. 366: 203–244.

Sykes, J. E. 1961. Contributions to the study of Chesapeake Bay striped bass. Chesapeake Sci. 2(1–2): 1–44.

Thoits, C. F., III. MS 1958. A compendium of the life history and ecology of the white perch *Morone americana* (Gmelin). Mass. Div. Fish. Game, Fish. Bull. 24: 1–16 + bibliography. (Mimeo.)

Van Oosten, J. 1942. The age and growth of the Lake Erie white bass, *Lepibema chrysops* (Rafinesque). Pap. Mich. Acad. Sci. Arts Lett. 27: 307–334.

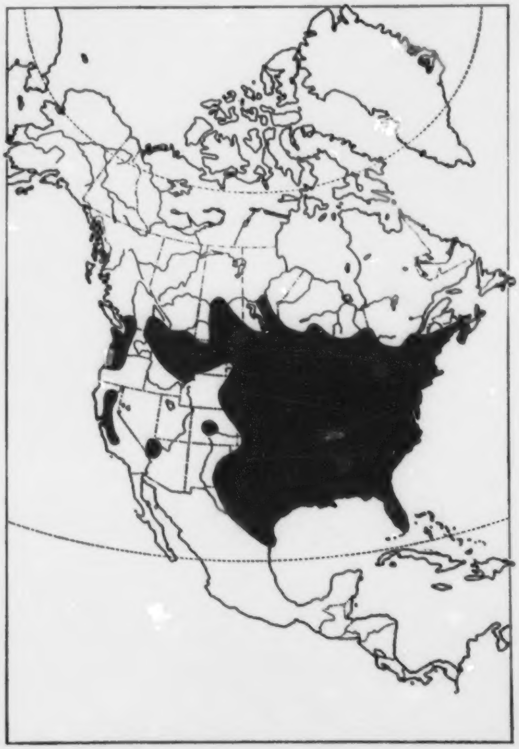
Woolcott, W. S. 1962. Infraspecific variation in the white perch, *Roccus americanus* (Gmelin). Chesapeake Sci. 3(2): 94–113.

SUNFISH FAMILY — Centrarchidae

These are, generally speaking, small to moderate-sized, spiny-rayed, gibbous, laterally-compressed, physoclistous fishes. The head and mouth are small to large; the eyes are large. Bands of villiform teeth are borne on the jaws, vomer, palatines, and tongue of most species. In some, the lower pharyngeal bones bear conical or flat teeth. The dorsal fin consists of a spinous portion (6–13 spines) and a soft-rayed portion, to a varying degree joined as 1 fin. The 2 parts are always more closely connected than in the closely related perches. The pectoral fins are moderately high on the body; the pelvic fins, of 1 spine and 5 rays, are thoracic. The anal fin is preceded by 3–9 spines and in some species equal in size to the dorsal fin. The caudal fin is, to a varying extent, forked.

This family includes some of the most highly coloured and attractive North American warmwater fishes, and several species are important sport fishes. Although originally restricted to eastern North America, various species, especially the basses, have been widely introduced elsewhere. Sunfishes inhabit the shallows of warm, rocky, and vegetated lakes, ponds, and slowly moving streams.

The family is composed of 30 species in 10 genera, generally grouped as sunfishes, crappies, and basses, and are known from the Miocene to Recent.



North American Distribution of the Sunfishes

KEY TO SPECIES

1 Dorsal spines 10–12; branchiostegal rays 6 (rarely 5 or 7); base of anal fin into base of dorsal fin 1.5–3.0 times 2

Dorsal spines 6–8; branchiostegal rays 7; base of anal fin equal to, or slightly longer than base of dorsal (crappies, *Pomoxis*) 9

2 Anal spines 6, spines arise in a scaled groove; body with 7–9 horizontal rows of black spots below lateral line; base of anal fin about 1.5 times into base of dorsal. .... ROCK BASS, *Ambloplites rupestris* (p. 703)

Anal spines 3, not in groove; no horizontal rows of spots below lateral line; base of anal fin into base of dorsal 2.1–3.3 times 3

3 Lateral line scales more than 55; greatest depth into length from tip of snout to end of scales 3.0–3.3 times (basses, *Micropterus*) 4

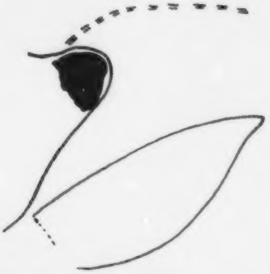
Lateral line scales fewer than 50; greatest depth into length from tip of snout to end of scales 2.0–2.5 times (sunfishes, *Lepomis*) 5

4 Upper jaw extends at least to mid-pupil, but not beyond eye; connection between dorsal fins higher, shortest posterior spine more than one-half the longest; 68–78 scales in lateral line; pelvic fins joined by membrane, membrane connecting fins to body hidden; young with conspicuous orange and black bands on caudal fin. .... SMALLMOUTH BASS, *Micropterus dolomieui* (p. 728)

Upper jaw extends beyond eye; connection between dorsal fins lower, shortest posterior spine less than one-half the longest; 60–68 scales in lateral line; pelvic fins not joined by membrane, membrane connecting fins to body obvious; young without colourful pigment on caudal fin but with prominent lateral band. .... LARGEMOUTH BASS, *Micropterus salmoides* (p. 734)

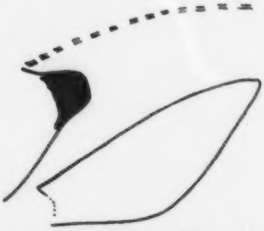
5 **Opercular flap in life with black centre, yellow, orange, or red spots or band around margin (in preserved specimens the once coloured areas are white or colourless)** 6

Opercular flap in life all black, not marked or edged by yellow, orange, or red in life (not edged with white or colourless in preserved specimens) 7

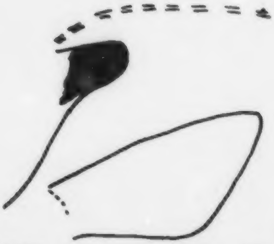


6 **Pectoral fins longer, 3 times in standard length, pointed at leading edge; gill rakers very short and knobbed; opercular flap short, black in centre, edged with white or yellow, with a prominent well-defined red spot at posterior edge.** .... **PUMPKINSEED,** ***Lepomis gibbosus*** **(p. 713)**

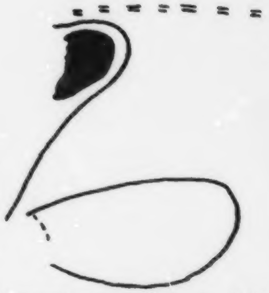
Pectoral fins shorter, 4 times in standard length and rounded; gill rakers short but not knobbed, or moderately long; opercular flap longer, black in centre, edged with yellow, orange, or red, no prominent, precise, red spot. 8



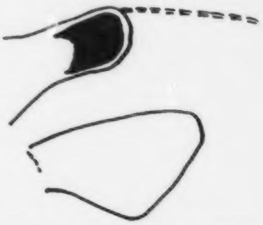
7 **Black area of opercular flap usually as deep as long, bony edge of flap entire, not crenate; gill rakers long and slender; pectoral fin long and pointed; base of anal fin into base of dorsal fins 2.0–2.3 times; ventral edge of preopercle finely serrate; black spot at posterior base of second dorsal fin.** .... **BLUEGILL,** ***Lepomis macrochirus*** **(p. 719)**



Black area of opercular flap usually longer than deep, bony edge of flap crenate; gill rakers short and stout; pectoral fin short and rounded or somewhat pointed; base of anal into base of dorsals 2.3–2.6 times; preopercle not serrate; no black spot at posterior base of second dorsal fin. .... **REDBREAST SUNFISH,** ***Lepomis auritus*** **(p. 707)**



8 Opercular flap as deep as long, black area edged with red and/or yellow, most prominently on bottom and end; bony edge entire, not crenate; scales smaller, 44 or more in lateral line, 8–10 diagonal rows of scales between lateral line and dorsal origin. .... GREEN SUNFISH, *Lepomis cyanellus* (p. 710)



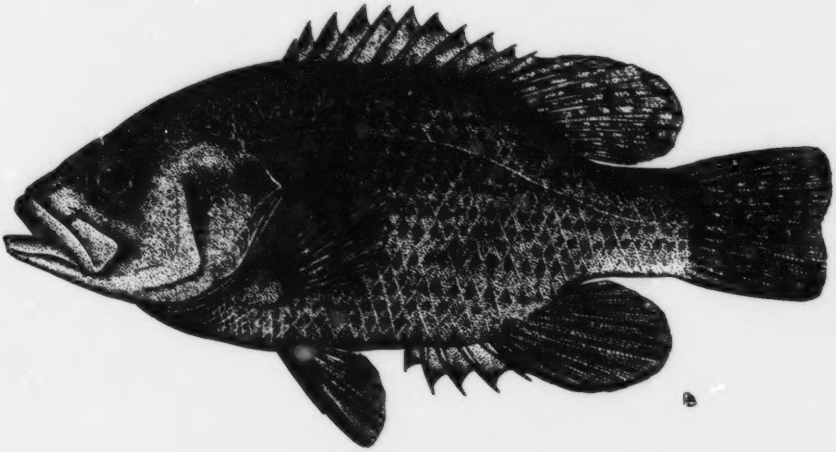
Opercular flap long, moderately wide, and turned up, black area completely edged with red and/or yellow; bony edge crenate; scales larger, 39 or more in lateral line, 4–6 diagonal rows between lateral line and dorsal origin. .... LONGEAR SUNFISH, *Lepomis megalotis* (p. 724)

9 Dorsal spines 6; base of anal fin longer than base of dorsal fins; eye diameter 5–6 times in head, 2 times in snout; body pale with vertical bars (prominent in life). .... WHITE CRAPPIE, *Pomoxis annularis* (p. 741)

Dorsal spines 7 or 8; base of anal fin almost equal to base of dorsal fin; eye diameter 4–5 times in head, less than 2 times in snout; body darkly and irregularly blotched with black. .... BLACK CRAPPIE, *Pomoxis nigromaculatus* (p. 745)

ROCK BASS

Ambloplites rupestris (Rafinesque)



Description Body deep, greatest depth at origin of dorsal fin 31.8–36.7% of total length, laterally compressed but less so than most other sunfishes (*Lepomis*, *Pomoxis*); individuals usually 6–10 inches (152–254 mm) in length; caudal peduncle almost as deep as long, depth about 12–14% of total length; angle from snout to dorsal fin not steep. Head rather large, narrow, and deep, length 30.4–34.5% of total length, mostly scaled, opercular flap (or ear flap) short, stiff, not brightly coloured; eye very large, diameter 26.7–40.9% of head length, high, well ahead of centre of head; snout moderately long, about 20% of head length, bluntly pointed; mouth terminal, slightly oblique, lower jaw slightly longer, maxillary long, 33.3–45.5% of head length, wide at tip and reaching to middle or posterior edge of pupil, gape reaching to pupil; fine brushlike teeth on palatines, vomer, tongue, and both jaws, those on lower jaw the largest, pharyngeal teeth numerous, short, fine and pointed, lower pharyngeal pad long and narrow. Gill rakers about 16, often 4 knoblike rudiments on upper limb, 6 long, fingerlike rakers and 6 rudimentary knobs on lower limb. Branchiostegal rays 6, or rarely 5. Fins: dorsals 2, but broadly joined and appear as 1, base of dorsal fins almost twice as long as anal base, first dorsal long and spiny, 10(1), 11(32), or 12(7) spines, fifth spine highest, edge rounded, last spine about ½ height of second dorsal, second dorsal soft rayed, higher, but with base about ½ that of first dorsal, rays 11(21) or 10(19), edge round; caudal only moderately broad and long, little to moderately forked, tips rounded; anal with long base (but only ½ length of dorsal base), 5(2), 6(36), or 7(2) rather short spines, and 10(33) or 9(7) soft rays, soft-rayed part dorsal, second dorsal soft rayed, higher, but bases of soft and spiny portions about equal, edge round; pelvics thoracic, origin under first or second dorsal spine, 1 spine and 5 rays, long, tip a blunt point, edge square to slightly rounded; pectorals moderately high, length about 18% of total length, broad and rounded, usually 13 rays but sometimes 12 or 14. Scales moderately large, ctenoid, dorsally somewhat crowded forward; lateral line complete, high on body, shallowly arched, lateral line scales 37–51. Peritoneum colourless; intestine long; 9 long, slim pyloric caeca on the single animal examined. Vertebrae 29 or 30 in Ontario.

No nuptial tubercles, but colour intensifies at spawning time.

Colour General colouration of dorsal surface of head, body, and upper sides golden brown, to olive; lower head, body below pectoral fins, and ventral surface silver to white; several vague saddle marks, bars, blotches or mottling over dorsal surface to lateral line; each scale below lateral line with black spot, forming 8–10 horizontal rows, less prominent in older and in smaller individuals; eye usually bright red to orange (hence common names redeye, goggle eye); opercular flap with vague black spot not reaching edge; dorsal and anal spines darker than membranes, some black pigment creating mottling or vermiculations on membranes of second dorsal, caudal, soft part of anal, and pelvic fins; edge of pelvic often white, pectoral fin dusky. At 2 inches (51 mm) length, pattern of sides is a general black marbling. The saddle marks of adults, inconspicuous during the day, become very obvious at night.

Systematic notes There seems to be no obvious meristic trends in the Canadian material examined (Quebec to Manitoba) except toward fewer lateral line scales in Manitoba.

Canadian populations are usually considered part of a form referred to as the northern rock bass, *A. r. rupestris*, distinct from the Gulf coast form *A. r. ariommus*. These two intergrade in Missouri and Arkansas.

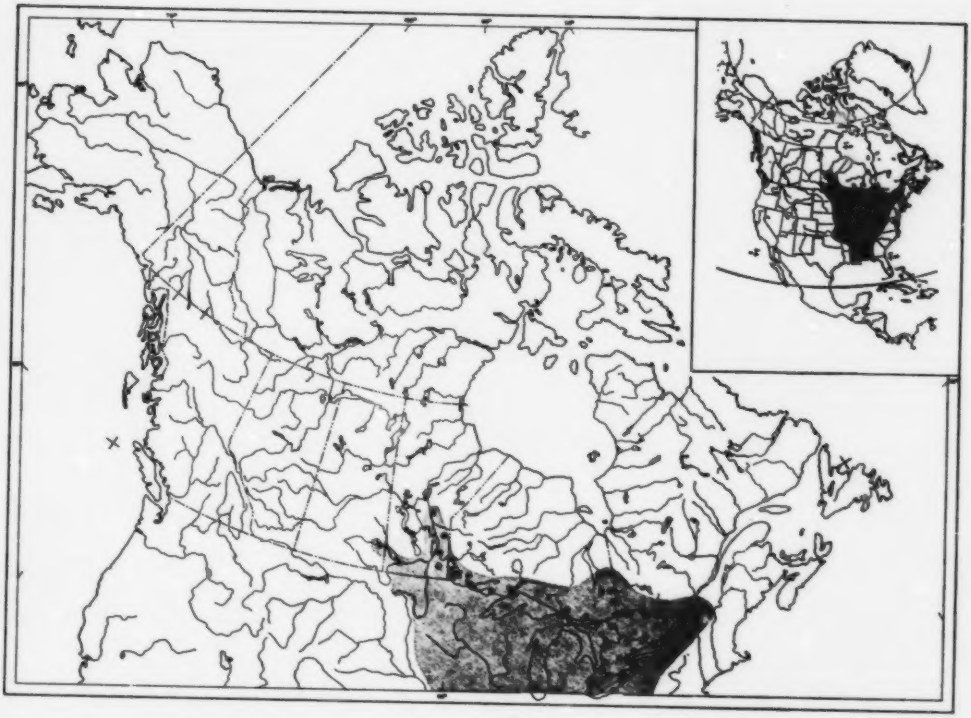
There is a superficially similar species, the warmouth, *Lepomis gulosus* (Cuvier) which occurs south of the Great Lakes, and has been often erroneously recorded in early Canadian lists and should be watched for in southwestern Ontario. The warmouth has only three anal spines.

Distribution The native range of the rock bass is restricted to the fresh waters of east-central North America. It occurs in the St. Lawrence River–Lake Champlain system, south, west of the Appalachian Mountains, to northwest Georgia, south to the Gulf coast from Florida panhandle to eastern Louisiana, north through central Arkansas, northeast Oklahoma, and southern Kansas (rare or introduced), north through the eastern parts of the states from Nebraska to North Dakota, in Saskatchewan, to central Manitoba and east to Quebec. Canal migrant to, and introduced into, the eastern coastal plain, introduced into Colorado, Wyoming, and probably other western states.

In Canada it occurs in southern Quebec, in the St. Lawrence–Lake Champlain system and in the Ottawa River system (introduced in Gatineau Lakes); throughout Ontario, north generally to a line below Lake Nipigon but including Lake Abitibi (Hudson Bay drainage), all the Great Lakes, absent from Lake Nipigon but present in Whitewater Lake (Ogoki River) now a tributary of that lake as a result of the Ogoki River diversion; west in the Hudson Bay drainage of western Ontario and eastern Manitoba; in the Red River system of Manitoba, north to central Lake Winnipeg; the Assiniboine River and in the Qu'Appelle River in eastern Saskatchewan.

Biology Although abundant in Canada, one must resort to Bensley (1915) and Hallam (1959) for scraps of first-hand information on biology of Canadian populations. Much of the following was taken from Breder (1936b), Breder and Rosen (1966), Beckman (1949), Carlander (1953), and Snow (1969).

Spawning takes place in the late spring and early summer, probably June in Canada, when the water temperature is 60°–70° F (15.6°–21.1° C). The male digs a shallow nest, up to 2 feet in diameter, in areas as diverse as swamps and gravel shoals. Often nests are very close together in an area heavily used at spawning time and defence of territory and attempts to attract and hold females are very aggressive. When spawning,



the male and female remain very near each other, the male upright but the female gradually reclining on her side. There is considerable vibration and the fish seem to rock back and forth while in a head to tail position. Spawning takes place at short intervals over a period of an hour or more but only a few eggs are laid at a time. More than one female may spawn in the same nest and one female may spawn in more than one nest. Egg number varies with size of female from 3000 to 11,000. The eggs are adhesive, and hatched in 3–4 days in aquaria at 68.9°–69.8° F (20.5°–21.0° C) (Breder 1936b). The female leaves the nest after spawning. The male guards and fans the eggs and later broods the young for a short period. Fish (1932) gave details of early development. Average number of fry, resulting from a nest in Michigan, was 800.

Growth is rapid and young-of-the-year in Ohio were 0.8–2.0 inches (20–51 mm) in October. There is apparently no available growth data for Canadian populations, but the following figures for 126 Michigan lakes and 6 Wisconsin lakes probably approximate the age–length relation in southern Canada.

	TL			
	Michigan (Beckman 1949)		N Wisconsin (Snow 1969)	
Age	(*inches*)	(*mm*)	(*inches*)	(*mm*)
0+	1.5	38	–	–
1+	3.2	81	1.8	46
2+	4.3	109	3.4	86
3+	5.2	132	4.7	119
4+	6.2	157	6.5	165
5+	7.3	185	7.5	190
6+	7.9	201	8.7	221
7+	8.8	224	–	–
8+	9.0	229	–	–
9+	9.9	251	–	–
10+	10.5	267	–	–
11+	–	–	–	–

A length–weight relation for Michigan has been given as log W = –4.44406+3.025

log SL. It would appear that maximum age in nature is 10–12 years but ages of 18 years in aquaria have been recorded. Size in Canada is usually 6–8 inches (152–203 mm) with some individuals to 10 inches (254 mm). Weights rarely exceed ½ pound. Trautman (1957) gave maximum size as 12.8 inches (325 mm) and 1 pound 4 ounces. He stated that adults were usually 4.3–10.5 inches (109–267 mm) in length and weighed 1–14 ounces. There is a record of an individual 13.4 inches (340 mm) in length weighing 3 pounds 10 ounces. In crowded ponds or smaller streams rock bass are often stunted and rarely exceed 9 inches (229 mm).

The rock bass, as indicated by its common name, generally inhabits rocky areas in shallow water in lakes, and the lower, warm reaches of streams. Adults are usually found in aggregations and most often in association with other sunfishes such as the smallmouth bass and pumpkinseed. The young are littoral to limnetic in various lakes. Extensive information on physical conditions in streams and fauna associated with the rock bass was given by Hallam (1959).

Food of this species is largely aquatic insects (immature and adult), crayfish, and small fishes, especially minnows, yellow perch, and at times their own young. Some food is taken at the surface. Keast and Webb (1966) listed the food in Lake Opinicon, Ont., as follows: up to 2.7 inches (70 mm)—chironomids (found in 50% of specimens examined), Ephemeroptera (35%), Odonata (30%), Cladocera (40%), Amphipoda (30%), Isopoda (15%), surface insects (35%), Copepoda and Hydracarina; more than 3 inches (76 mm)—Odonata (to 75%), Ephemeroptera (35%), Trichoptera (35%), fish fry (30%), crayfish (15% and over); between 4.7 and 7.8 inches (120–200 mm)—almost entirely crayfish and Anisoptera.

Keast and Welsh (1968) described details of food uptake and diel dietary changes in this species. Keast (1968b) described feeding in winter.

The young and smaller adults are probably preyed upon by large basses, by northern pike and muskellunge, and possibly by walleyes. They, no doubt, compete with smallmouth bass for food.

Bangham and Hunter (1939) listed the parasites of this species in Lake Erie.

Parasites listed by Hoffman (1967) were: Protozoa (5), Trematoda (35), Cestoda (8), Nematoda (13), Acanthocephala (9), leeches (3), Crustacea (9).

One parasite seen regularly on this species is black-spot — the resting stage of a trematode of which the belted kingfisher is the final host. It causes the development of small black spots on the fins, but cannot harm humans.

Relation to man This species may be important in an indirect way in its ecological association with other species more valued by man, such as the basses. It is a commercial species in the Great Lakes and Mississippi River and is an important sport fish elsewhere. It is not often directly sought by Canadian anglers, except children, and rarely eaten if caught incidental to other fishes. Its flesh is firm, white, flaky and delicious. A concern over the effort required to clean such small fish has lost many an angler a delicious meal. Rock bass strike live or artificial bait hard, fight hard, and provide good sport on light tackle. They can be readily taken on live bait, flies, small spinners, plugs, and poppers. They are often caught when stillfishing, casting, or trolling at depths too shallow for bass, northern pike, or walleye.

Commercial production of this species in Canada is significant in Ontario only. The catch of rock bass is combined in the statistics with that of the crappies, but the rock bass must contribute the bulk. The Ontario catch in 1966 was 271,411 pounds, with a value of $60,417.45. The major areas, in descending order of catch, were lakes St. Clair, Erie, and Ontario, northern inland lakes, southern inland lakes, North Channel, and Lake Huron.

Nomenclature

Bodianus rupestris — Rafinesque 1817b: 120 (type locality lakes of New York, Vermont and Canada)

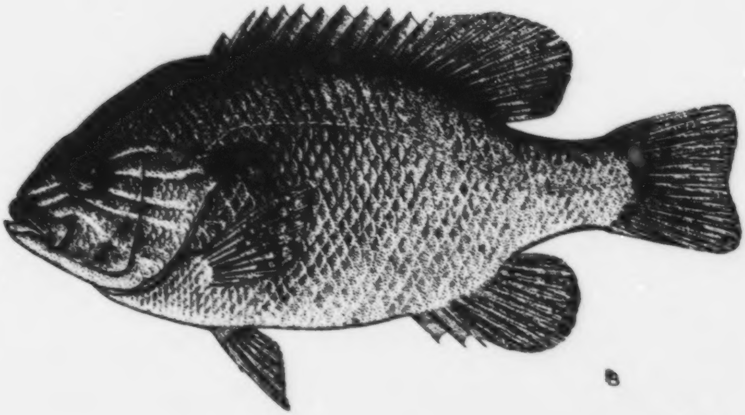
Cichla aenea — LeSueur 1822a: 214
Centrarchus aeneus (Cuvier) — Richardson 1836: 20
Ambloplites rupestris (Rafinesque) — Jordan and Gilbert 1883a: 466
Ambloplites rupestris rupestris (Rafinesque) — Hubbs 1947: 94

Etymology *Ambloplites* — blunt armature; *rupestris* — living among rocks.

Common names Rock bass, northern rock bass, redeye, redeye bass, goggle eye. French common name: *crapet de roche*.

REDBREAST SUNFISH

Lepomis auritus (Linnaeus)



Description Body very deep, depth at dorsal origin 32.2–39.9% of total length; individuals usually 5–7 inches (127–178 mm) long; strongly laterally compressed, angle from snout to dorsal moderately steep, convex, back somewhat flattened under dorsal fin, caudal peduncle longer than deep, its depth 12–14% of total length. Head very deep, long, length 28.2–30.3% of total length, narrow, angle steep, hump over the eye; opercular flap soft, quite long in adult males, shorter in females and juveniles, twice as long as wide, black (no coloured border), bony edge well removed from edge of flap and crenate; eye moderately large, diameter 20.4–26.9% of head length, well ahead of centre of head, moderately high; snout length 21.9–27.7% of head length; mouth terminal, somewhat oblique, not large, lower jaw somewhat longer than upper, gape not reaching anterior edge of eye, maxillary short, length 30.3–34.9% of head length, reaching only to anterior edge of eye; many short needle-like teeth on jaws, and palatine, lower pharyngeal teeth on long, narrow pads, short and pointed. Gill rakers short and stout, knoblike only at upper and lower ends of series, about 8 on lower limb, 5 on upper limb. Branchiostegal rays 5 on material examined, but said by McAllister (1968) to be 6 or 7 and rarely 5. Fins: dorsals 2, but broadly joined and appear as one, base of dorsal fins 43.4–49.4% of total length and about 2½ times as long as base of anal fin; first dorsal fin long, spiny, rather low, 10 or 11 spines, little difference in length, edge almost flat, length of last spine about ½ that of soft dorsal fin; second dorsal fin soft rayed, higher but with base only a little over ½ that of first dorsal fin, rays 10–12, usually 11, edge round; caudal only moderately broad, long, and forked, tips rounded; anal with only moderately long base, 21.6–25.0% of total length, but less than ½ dorsal base, usually 3, but rarely 4, short, sharp spines followed by 9 or 10 soft rays, base and height of spiny portion about ½ those of soft-rayed portion, edge of soft portion rounded; pelvics thoracic, origin under first dorsal spine, 1 small spine and 5 rays, fin not long, tip pointed, edge square; pectorals moderately high on body, short, length 15.5–19.7% of total length, edge rounded, usually 14, but rarely 13 rays. Scales ctenoid, rather small, crowded anteriorly (dorsal) and posteriorly; lateral line complete, high on body except on peduncle, flatly arched beneath base of dorsal fins, 43–49 lateral line scales. Peritoneum colourless, intestine well differentiated, usually 7 moderately long pyloric caeca. Vertebrae usually 29 or 30.

No nuptial tubercles but colours intensify considerably in breeding males.

Colour Body usually golden brown to olive, dorsal surface darker, sides lighter with inconspicuous reddish spots and vague, blue streaks, breast yellow to bright orange-red, hence previous and present common names, yellowbelly sunfish and redbreast sunfish; opercular flap blue-black to black to tip, no white or bright colours around margin; fins dusky to mottled with darker pigment, leading edge and tip of pectoral fins dark.

Systematic notes There is often confusion between this species and the longear sunfish. The "ear" flap or opercular flap is longer in mature male redbreast sunfish than in longear sunfish, but may be shorter in females and juveniles. The two are readily separated in that only *L. auritus* has palatine teeth, opercular flap without white or coloured border, gill rakers short but not blunt knobs in centre of series.

Until recently this species was called yellowbelly sunfish. *See* Scott and Crossman (1959) concerning confused synonymy in New Brunswick.

Distribution The redbreast sunfish occurs only in eastern North America. Its range extends from New Brunswick south, east of the Appalachian Mountains, to central Florida, west to the Apalachicola River, apparently not in Mississippi but introduced into Texas and Oklahoma.

In Canada, it is known only in New Brunswick. It occurs there in the systems of the Canaan, Kennebecasis and Oromocto rivers, Oromocto Lake, Anne Lake and possibly in Yoho Lake and the Magaguadavic River. It may occur more widely but goes unreported, as a result of being mistaken for the more common pumpkinseed. This species has been entered in New Brunswick checklists from as early as 1896 (Cox 1896a) on the basis of its presence in Maine or confusion with the pumpkinseed. The first authentic record, however, was a specimen from the Canaan River, Queens County, captured by H. C. White on September 3, 1948.

Biology There is no published information available on the biology of this species in Canada. The redbreast sunfish spawns in the spring or early summer (*see* Breder 1936b; Breder and Rosen 1966). Redbreast sunfish spend the winter in deeper water in a wintering school or hibernium (Breder and Nigrelli 1935). This aggregation breaks up when the temperature reaches 50° F (10° C) and individuals (males first) make their way to the shallows along the shores. Males defend territories and dig a nest, sometimes as large as 24–40 inches (61.0–101.6 cm) in diameter, and in water 6–18 inches (152–457 mm) deep. In ponds or lakes, the nests are often close together and in the open; in streams they are in the current but usually on the downstream side of a protective rock. Apparently this species will occupy the unused nests of other centrarchids including largemouth bass. Nests have been found from June 6 to August 12 in New York, and the peak in spawning activity generally occurs in mid- to late June when water temperatures are 62°–82° F (16.7°–27.8° C). Richmond (1940) described what was apparently successful nesting in tidal water in Virginia (brackish?) where water temperature, water depth (almost exposed at low tide), and salinity varied drastically. The eggs are moderate in size amber to yellow, and adhesive. The female leaves the nest after the eggs are laid and fertilized. The male guards the nest, fans the eggs to prevent suffocation by silting, and may even guard the newly hatched young for a short time.

Nothing is apparently available on the age–length relation of this rather small and uncommon sunfish. They are said to grow only to 6 inches (152 mm) in Maine, but are known to 9.4 inches (239 mm) and 11 ounces in Connecticut. In New Brunswick they grow at least to 8 inches (203 mm) but those usually seen are 5–7 inches (127–178 mm) in length.

The habitat of this species is variable over its range. In New Brunswick they appear to inhabit the rocky areas of streams and lakes and are fairly abundant on shores of loose rock. In streams with rapids, they occur in the slower, deeper areas of rock and gravel. In lakes they occur in quiet, deeper water over bottoms of sand to mud with abundant emergent vegetation. They apparently live rather independent lives in the summer but when water temperatures drop below about 41° F (5° C) they aggregate in schools in deeper holes and remain there all winter. Amount of activity in summer shows a direct relation to amount of sunshine and to water temperature. This sunfish, in New Brunswick, apparently darts under rocks when disturbed, much as rock bass do, but unlike the other species of sunfish, such as the pumpkinseed, which occur there.

Food of the redbreast sunfish is mainly immature aquatic insects but adult insects, molluscs, other bottom invertebrates, and possibly small fishes make up a minor part of their diet.

The chain pickerel, the brown bullhead, and the eel, may consume smaller redbreast sunfish and are the only likely predatory species in the Canadian range of this sunfish. A wide variety of fishes including minnows and other redbreast sunfish will eat the eggs in an unguarded nest.

Parasites listed by Hoffman (1967) were: Trematoda (2), Nematoda (1), Acanthocephala (1), leeches (1), Crustacea (1).

Natural hybrids are known between this species and the warmouth, the pumpkinseed, green sunfish, and bluegill.

Relation to man This species would appear to be one of the least important sunfishes over the whole of its range. This is no doubt due to the fact that larger species of sunfishes occur throughout its range.

Warmwater fishes are not highly regarded in New Brunswick so it is not surprising that this uncommon sunfish is of little importance. Its flesh is white, flaky and as good to eat as any. Some are caught by anglers, mainly boys, but are small and rarely kept. They are locally abundant, will readily take live bait and can be caught on flies and small "bugs." If fished with light tackle, they would provide fair sport.

Nomenclature

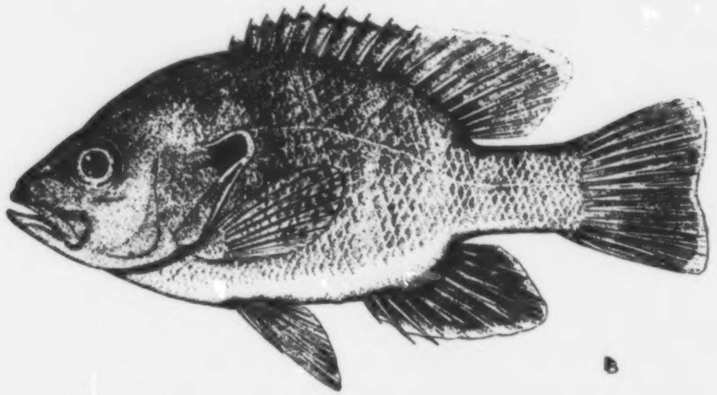
Labrus auritus — Linnaeus 1758: 283 (type locality Philadelphia, Pa.)
Lepomis auritus (Linn.) Raf. — Cox 1896b: 70
Pomotis appendix Storer — Cox 1896b: 70
Pomotus rubricauda Storer — Jordan and Evermann 1896–1900: 1001
Lepomis auritus Linnaeus — Halkett 1913: 82
?*Apomotis cyanellus* (Raf.) — Cox 1924: 85
Eupomotis auritus Linn. — Cox 1924: 86
Pomotis rubri-cauda Storer — Jordan, Evermann, and Clark 1930: 299

Etymology *Lepomis* — scaly operculum, a character supposed to distinguish this genus from *Sparus*; *auritus* — eared, alluding to the long opercular flap.

Common names Redbreast sunfish, yellowbelly sunfish, longear sunfish, longears. French common name: *crapet rouge*.

GREEN SUNFISH

Lepomis cyanellus Rafinesque



Description A deep-bodied, laterally compressed fish, usually not over 5 inches (127 mm) in length in Canada. Body not so deep as, and thicker than, other sunfishes. Greatest depth at origin of dorsal fin 30.3–34.1% of total length; caudal peduncle a little longer than deep, depth 12–13% of total length; angle from snout to dorsal fin not steep, back only shallowly arched. Head rather large, length 27.8–31.9% of total length, deep and heavy, but narrow, mostly scaled, depression over eye, opercular flap long but almost as deep as long, stiff to margin, black in centre with coloured margin; eye large, diameter 18.6–31.3% of head length, in advance of centre of head, moderately high; snout bluntly pointed, moderately long, about 30–35% of head length (including bony part of opercular flap); mouth terminal, oblique, large, gape reaching to anterior edge of eye, jaws usually equal, lips large; maxillary long, 30.0–41.9% of head length, reaching to centre of pupil; fine teeth on palatines, vomer and both jaws, absent on tongue; pharyngeal teeth larger, less numerous, conical, lower pad much longer than wide. Gill rakers in centre of arch long and thin, about 14 on lower limb and 4 or 5 on upper limb (including rudiments). Branchiostegal rays usually 6, but rarely 7. Fins: dorsals 2, but broadly joined and appear as one, base of dorsal fins about 2½ times anal base, first dorsal long, spiny, 9–11 but usually 10 spines, edge only slightly rounded, almost flat, longest spine less than ½ height of second dorsal, second dorsal soft rayed, higher, base length over ½ that of first dorsal, rays 10–12, usually 10 or 11, edge rounded, to slightly pointed in breeding males; caudal rather broad, shallowly forked, tips rounded; anal with base less than ½ length of dorsal base, 3 sharp spines and 9 or 10 soft rays, soft-rayed part not greatly higher than third spine but base of soft portion over 3 times that of spiny portion, edge round, to slightly pointed in breeding individuals; pelvics thoracic, origin under first dorsal spine, rather long, 1 spine and 5 rays, spine about ½ length of fin, tip pointed, edge square to slightly rounded; pectorals moderately high, not long, length 17.9–21.2% of total length, broad, tip round, usually 13 rays but sometimes 12. Scales rather small, ctenoid, somewhat crowded both anterior (dorsally) and posterior; lateral line complete, high, shallow arch over pectoral fin, lateral line scales 40–50, 8–10 scale rows above lateral line. Peritoneum white to silvery; intestine long, well differentiated, 6–8 pyloric caeca. Vertebrae 28 or 29 on material examined.

No nuptial tubercles but colour and pattern intensify at spawning time.

Colour Body generally brown to olive with an emerald sheen, darker on dorsal surfaces and upper sides, sides light yellow-green, upper sides with 7–12 dark but vague, vertical bars; ventral surface yellow to white, breast not conspicuously coloured; head with emerald spots, and at times, wavy, radiating, emerald lines; opercular flap with squarish black centre, entirely edged with pale red, pink or yellow, brightest at tip and below; in spawning males, the dorsal, caudal, and anal fins dusky to olive, membranes darker, and edged with white, yellow, or orange border; sometimes the body of these fins has small, light spots, usually a vague, dark spot at base of last rays of dorsal and anal fins; paired fins clear, or pelvic fins dusky to olive. Young without emerald colouring, dark bars, or fin spots.

Distribution The green sunfish is restricted to the fresh waters of east-central North America. It occurs south from southwest New York, west of the Appalachian Mountains, to Georgia, Alabama (west of the Escambia River), absent until recently, from the Florida panhandle, west and south to Texas and northeastern Mexico, north through the eastern parts of the states from New Mexico to Wyoming, to eastern North Dakota, east below the Red River system (but in the Hudson Bay drainage of western Ontario) to Michigan and Ontario. Introduced elsewhere, and, as a result, known to occur at least in Utah and California.

In Canada, this species is restricted to Ontario where it has a disjunct distribution, and, although abundant in certain restricted areas, is not well known even in those areas. It occurs in southwestern Ontario in the Thames–Avon system tributary to Lake St. Clair and in northwestern Ontario in several lakes in Quetico Provincial Park (Hudson Bay drainage). In the Lake St. Clair system it is abundant in Irish Lake (Avon River), Grey Co., and Fanshawe Lake (Thames River), Middlesex Co., Ont. As a result of its proximity in New York State, it should be watched for in the Niagara District.

An early report of *Apomotis cyanellus* from Yoho Lake, Oromocto Co., N.B., (Cox 1924) was probably based on a redbreast sunfish.

Biology Information on the biology of the green sunfish in Canada is not available. *See* Hunter (1963) for details of sexual dimorphism and reproductive behaviour in ponds in Wisconsin. This species spawned in late spring and summer. Multiple spawnings occurred every 8 or 9 days from mid-May to early August. The peak in activity occurred over a range of water temperatures from 68.0°–82.4° F (20°–28 °C). Males were territorial and each built one or more shallow nests very close together in a nesting colony, in sunlit water 1.5–13.7 inches (40–350 mm) deep, in areas sheltered by rocks, logs, and clumps of grass, or they utilized abandoned nests. Fish, gathered about a digging male, were stimulated by its activity and began to nest nearby. Each spawning took place over a period of 1 or 2 days. Male and female swam around in the nest, came to rest with male upright and the female inclined, and during vibrations, eggs were laid and fertilized.

The male guards and fans the eggs, and probably guards the newly hatched young for a short period. The eggs are yellow, adhesive, and probably hatch in 3–5 days. An interesting spawning relation apparently exists, at least in Wisconsin, between redfin shiners and green sunfish. Spawning of green sunfish triggers spawning in the shiner and the latter lay their eggs in occupied nests of the former (Hunter and Wisby 1961; Hunter and Hasler 1965).

Growth is rapid, young-of-the-year in Ohio were 0.8–2.5 inches (20–64 mm) long by October. There is no complete growth data for Canada but the following table with relation between age and average standard length for green sunfish in Michigan (Hubbs and Cooper 1935) probably approximates it.

Age	SL	
	(inches)	*(mm)*
0+	0.8	19
1+	1.7	43
2+	2.5	63
3+	3.4	86
4+	4.0	102
5+	4.9	125
6+	5.2	132
7+	6.0	152

Trautman (1957) gave 10.8 inches (274 mm) length and a weight of 14.5 ounces as the maximum in Ohio. There is a record of an individual from Kansas which was 12 inches (305 mm) long and weighed 2 pounds 2 ounces. Specimens from Belles Lake (Grey Co.), Ont., between 6.7 and 7.5 inches (170–190 mm) in fork length, were estimated to be 5 years of age. Green sunfish, therefore, probably grow to at least 8 inches (203 mm) total length in Ontario. It would appear that life expectancy in nature is 7–9 years. Stunting occurs readily in crowded ponds and, in places, green sunfish are mature at 3 inches (76 mm).

In Ontario this species has been found in the shallows of moderate-sized, clear to somewhat turbid lakes, and an impoundment (Fanshawe Lake). Elsewhere it is found in small streams, ponds, impoundments, temporary drainage ways, and lakes, with no noticeable preference for bottom type. They frequent brush piles and dense growths of emergent vegetation. The green sunfish is apparently more tolerant of turbidity than the other species of sunfish occurring in Canada. Certain physical characteristics of habitats containing green sunfish (Thames River), and the species associated with them were given by Hallam (1959).

The food of this species, like the other sunfishes, is probably largely insects, molluscs and small fishes. Carp and bass have also been reported. The large, heavy mouth would suggest the ability to eat large and hard-bodied organisms.

Green sunfish, rarely very large, probably fall prey to a wide variety of warmwater fishes with which they live, the basses *(Micropterus)* in particular.

Parasites of the green sunfish listed by Hoffman (1967) were as follows: Protozoa (4), Trematoda (29), Cestoda (5), Nematoda (7), Acanthocephala (2), leeches (1), Mollusca (1), Crustacea (4).

This species is known to hybridize in nature with longear sunfish, bluegill, orangespotted sunfish, pumpkinseed and redbreast sunfish.

Relation to man In Canada the green sunfish bears little relation to man. In areas in southwest Ontario where they are locally abundant they may be angled for by children. They can be taken with live bait, flies, or small spinners and poppers. They apparently strike hard but struggle little. They are doubtless good eating although small. In some areas of the United States, they are an important game fish.

Nomenclature

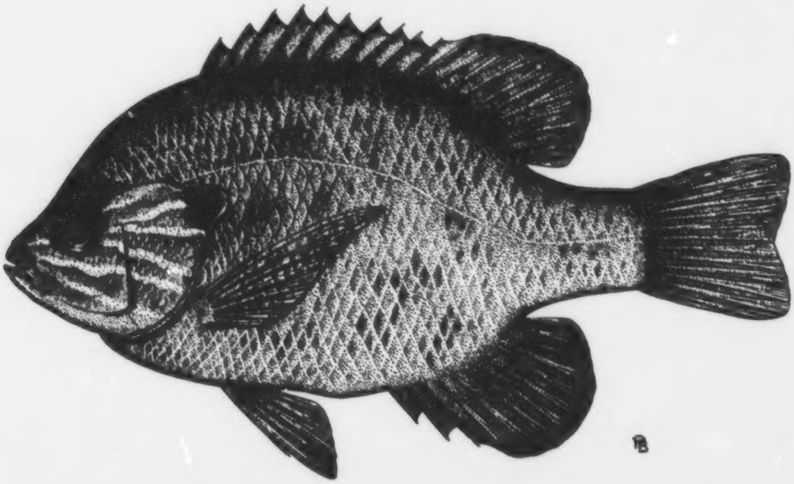
Lepomis cyanellus — Rafinesque 1819: 420 (type locality Ohio River)
Apomotis cyanellus (Rafinesque) — Jordan and Evermann 1896–1900: 996

Etymology *Lepomis* — scaled operculum; *cyanellus* — blue.

Common names Green sunfish, green perch. French common name: *crapet vert.*

PUMPKINSEED

Lepomis gibbosus (Linnaeus)



Description This is the common sunfish for all but a few locations of Canada. A very deep-bodied, laterally compressed, almost disc-like fish, usually 7–9 inches (178–229 mm) in length; greatest body depth at the fifth or sixth dorsal spine, 27.8–42.5% of total length, angle from snout to origin of dorsal fin steep, back humped, rounded even under dorsal fins; caudal peduncle longer than deep, its depth 10.7–15.1% of total length. Head quite deep, rather long, length 26.1–31.5% of total length, narrow, angle steep, pronounced hollow over eye, opercular flap flexible only at tip, black at centre with narrow, coloured border and red spot; eye moderately large, diameter 21.7–36.1% of head length, ahead of centre of head and moderately high; snout length 19.5–29.0% of head length; mouth terminal, only slightly oblique, rather small, gape reaching only to anterior nostril; maxillary short, 27.3–36.0% of head length, reaching to posterior nostril or anterior edge of eye; many short needle-like teeth in brushlike patches on jaws, and a single row on vomer, no palatine teeth; lower pharyngeal teeth, on pads at least ½ as wide as long, fewer, low, blunt and paved. Gill rakers short, stubby, about 8 on lower limb, 4 on upper. Branchiostegal rays 6, 6 and 7, or 7. Fins: dorsals 2, broadly joined and appear as one, base of dorsal fins 45.6–49.6% of total length, usually at least twice length of anal base; first dorsal long, spiny, moderate height, 10 or 11 spines but usually 10, not greatly different in length, last spine about ⅔ height of second dorsal; second dorsal soft rayed, higher, but with base only ⅔ that of first dorsal, rays 10–12, usually 11, edge shallowly rounded; caudal only moderately broad, somewhat longer, shallowly forked, tips rounded; anal fin with base 22.8–25.7% of total length, less than ½ dorsal base, 3 sharp spines precede the 8–11 (usually 9) soft rays, base of spiny portion about ⅓ length of base of soft part, but height is over ½ height of soft part; pelvics thoracic, origin under first or second dorsal spine, 1 spine and 5 soft rays, fin moderately long, tip pointed, edge square; pectorals moderately high on body, not overly broad but long and pointed, length 20.5–30.0% of total length, 12–14, but usually 13 rays. Scales usually ctenoid, not large, crowded dorsally front and rear; lateral line complete, high with long shallow arch over pectoral fin, 35–47 lateral line scales. Peritoneum silvery; intestine well differentiated, usually 7 or 8 moderately long pyloric caeca. Vertebrae almost always 29, rarely 28.

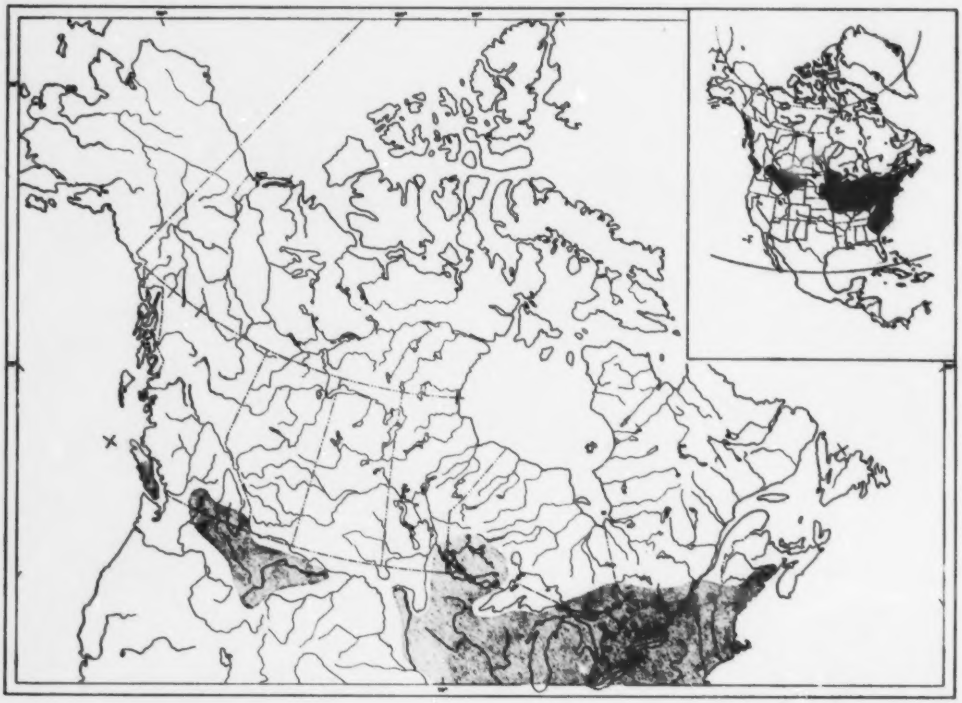
No nuptial tubercles but colours intensify at spawning time.

Colour Dorsal surface of head, body, and upper sides golden brown to olive, lower sides golden with irregular, wavy, interconnecting blue-green lines, ventral surface bronze to red-orange; sides of body and head flecked with spots of olive, orange, or red and with blue, emerald, or green reflections. Sides with several vague vertical bars; sides of head with prominent, wavy, blue-green stripes; pupil of eye black, a narrow, iridescent, golden ring around this and larger area brownish dorsally, blue-green ventrally; opercular flap with wide, black centre, a narrow border of white, yellow, orange, or blue with small halfmoon spot of bright red (sometimes orange, pink, or yellow) at tip; leading edge of dorsal spines black, membranes of second dorsal, caudal, anal, and pelvic fins black but no pronounced or distinct large black spots, small vague orange to olive spots on membranes of second dorsal and caudal fins, leading edge of pelvic whitish, trailing edge of second dorsal, caudal, and anal with narrow, iridescent yellow or blue-green edge; pectoral fins amber and clear.

Females paler; vertical bars more prominent. Hue of pattern variable depending on state and condition of individual, water clarity, and background. All colours intensified in breeding males. Young with much less colour pattern and only green to olive background colour.

The very common hybrid between this species and the bluegill more closely resembles this species in colour and opercular flap pattern. The hybrid usually has a vague suggestion of the spot at the posterior base of the second dorsal characteristic of the bluegill.

Systematic notes This species is not usually divided into subgroups. In the material examined the only suggestion of meristic variability was a slight tendency for western populations to have one more dorsal and anal soft ray.



Distribution The native distribution of the pumpkinseed is restricted to the fresh waters of eastern North America. It has, however, been widely introduced elsewhere in North America, England, France, the Low Countries, Germany, and the basin of the Danube River.

In North America it occurs from New Brunswick south along the Atlantic seaboard to northeastern Georgia. West of the Appalachian Mountains it occurs from southern Quebec to southern Ohio, west to northern Missouri, north through eastern South Dakota to eastern Manitoba, east through western Ontario, Minnesota to Michigan and across southern Ontario. Introduced at least into California, Wyoming, Montana, Washington, and Oregon, and probably many other states west of its natural range.

In Canada it occurs from southwestern New Brunswick, southern Quebec including the St. Lawrence River and tributaries, Lake Champlain, eastern Townships and the Ottawa River and its tributaries (introduced northward in Quebec). This is the common sunfish in Ontario, occurring generally north to a line from the Ottawa River, north of Lake Nipissing to Sault Ste. Marie. It is absent west to the height of land but present in the Nelson River drainage of western Ontario and southeastern Manitoba. It occurs in southeastern British Columbia as natural migrants from individuals introduced in the Columbia River in the United States, and in southern Vancouver Island as a result of introductions.

Biology One of a very few published studies of the biology of this species in Canada is that of Reid (1930) in New Brunswick. Spawning of this very decorative sunfish usually begins in late spring to early summer, although nests were occupied as late as July 11 in New Brunswick, and Bensley (1915) stated that spawning continued to the end of August in Georgian Bay. The nest, constructed by the male, is in the shallow water of ponds, lakes, or slow moving streams, usually in depths of 6–12 inches (152–305 mm) near shore. Nest building by males begins when water temperature reaches approximately 68° F (20° C) but nesting has been noted in August at 82° F (27.8° C). Nests are shallow depressions 4–16 inches (102–406 mm) in diameter, (usually 2 × length of adult), are found in areas of submerged aquatic vegetation, and often are numerous and very close together. Bottom type can be clay to sand, gravel or rock, as the male sweeps only deep enough to expose a clean, hard bottom. Often exposed roots are used for egg attachment. Sex recognition, courtship, and spawning behaviour were described by Noble (1934) and Breder (1940), and summarized by Breder and Rosen (1966). There is considerable display and swimming in a circular path during courtship and mating. Mutual bunting and nipping also stimulates spawning. Egg laying takes place during these circulations with the male upright and the female at a 45° angle, so that their ventral surfaces are together. Small numbers of eggs and small quantities of sperm are emitted at irregular intervals. Males may spawn more than once in the same season, in the same nest, with the same or different females. Eggs, which are pale amber in colour and about 1 mm in diameter, adhere to the bottom of the nest on soil particles, small stones, roots, and sticks. Egg number increases with size and has been given (Ulrey et al. 1938), for females 2–5 years of age and 2.9–3.7 inches (61–92 mm) in length, as 600–2923 with the average number per female ranging between 1684 and 2923. Elsewhere it was estimated to be as high as 5000. Obviously more than one female may spawn in one nest as Carbine (1939) counted the fry associated with individual nests and reported the numbers to range from 1509–14,639, with an average of 8074. The male guards the eggs and fans them, and guards the newly hatched young for a period of a few days. Hatching takes place in as little as 3 days at 82.4° F (28° C). The newly hatched young are minute and transparent, for some time only the dark eyes are visible. Fish (1932) gave details of the development of the young. For a period of up to eleven days the male guards the young, returning them to the nest in his mouth if they stray. After this time, the young leave the nest and the male may begin to clean the nest in preparation for a second spawning. Shoemaker (1947) reported what appears to be a case of mutualism in the association of a chain pickerel and pumpkinseed. The chain pickerel remained undisturbed over the pumpkinseed's nest and fed on golden shiners which moved in to eat the sunfish eggs in the absence of the male pumpkinseed.

Growth is moderately fast, with young-of-the-year in Ohio reaching 0.8–3.2 inches (20–81 mm) in length in October. The following table gives age–length relation for pumpkinseeds in New Brunswick (Reid 1930), and Ontario (MacKay 1963) and compares these with that for Michigan (Bailey and Lagler 1938).

Age	Welch Lake N.B. Avg SL		Various Ontario lakes FL		Michigan pond TL	
	(inches)	*(mm)*	*(inches)*	*(mm)*	*(inches)*	*(mm)*
0	1.0	25	–	–	2.0	51
1	2.9	74	3.5	89	2.9	74
2	3.5	89	4.2–6.0	107–152	4.1	104
3	4.1	105	4.7–7.2	107–183	4.9	124
4	4.4	111	4.8–8.2	122–208	5.7	145
5	4.6	116	6.3–8.0	160–203	6.2	157
6	4.7	120	7.0–8.7	178–221	6.8	173
7	4.9	125	7.5–9.0	190–229	7.3	185
8	–	–	8.7–9.1	221–231	7.8	198
9	–	–	8.5–9.5	216–241	–	–

Weights in the Lake Simcoe area of Ontario increased from 1–2 ounces at age 3, to 8–12 ounces at age 7. The larger, older Ontario fish were from the St. Lawrence River. Comparisons are difficult from the table as a result of the different lengths used, but Smith (1952) said that growth in Welch Lake, N.B., was somewhat faster to 4 years of age than that for particular habitats in Michigan, after that, growth in Michigan was faster. In small productive bodies of water with large populations, stunting takes place and maximum length may not exceed

4–5 inches (102–127 mm). Sexual maturity is usually achieved by age 2.

Maximum size and age in Ontario would appear to be about 10 inches (254 mm), 17 ounces, and 8–10 years. This is interesting in light of the fact that Trautman (1957) gave maximum length for Ohio as 8.8 inches (224 mm) and weight of 11 ounces. The pumpkinseed has dispersed farther north than the other lepomid sunfishes and may do better in Canada than in the southern part of its range.

This sunfish is usually found in small lakes, ponds, shallow, weedy bays of larger lakes, and in the quiet water of slow-moving streams. It prefers clear water and the cover of submerged vegetation or brush, and ranges over various type of bottom. They are usually seen in large numbers and often near, or at, the surface of areas exposed to the sun. It is one of the most widely distributed fishes in Ontario and often makes up the largest part of the fish population of small bodies of warm water. Black (1953) determined the upper lethal temperature for pumpkinseeds, acclimated at 64.4° and 75.2° F (18° and 24° C), to be 82.4° and 86.4° F (28.0° and 30.2° C). Brett and Sutherland (1965) gave figures on respiratory metabolism in relation to swimming speed.

In virtually the only published study of a Canadian population of this species, Reid (1930) said that food taken in Welch Lake, N.B., was, in descending order of frequency, as follows: dragonfly nymphs, ants, larval salamanders, amphipods, mayfly nymphs, midge larvae, roundworms, snails, water boatman, and other insect larvae. Food is mainly a variety of insects and, secondarily, other invertebrates with some shift according to size and season. Small fishes or other vertebrates (such as the larval salamanders mentioned above) can at times contribute as much to the diet of the adults as the most frequently eaten insects. Food is taken at the surface as well as off the bottom and in the water mass. Keast and Welsh (1968) described details of food uptake and diel dietary changes in this species. Keast (1968b) described feeding in winter.

Small pumpkinseeds form part of the food of almost all predatory fishes, and to a lesser extent of the pumpkinseed and other sunfishes. They are eaten by the basses, walleye, yellow perch, northern pike, and muskellunge.

Bangham and Hunter (1939) listed parasites of this species from Lake Erie, Bangham and Venard (1946) from Algonquin Park, Ont., and Bangham (1955) from Lake Huron.

Parasites listed for this species over the whole of its range by Hoffman (1967) were: protozoans (5), trematodes (60), cestodes (8), nematodes (14), acanthocephalans (7), leeches (3), molluscs, crustaceans (6), and linguatulans (1).

One parasite seen regularly on this species is black-spot — the resting stage of a trematode of which the belted kingfisher is the final host which causes small black spots on the fins.

The pumpkinseed is known to hybridize in nature with the warmouth, and the redbreast, green, orangespotted, bluegill, and longear sunfishes. Hybrid sunfishes are often fertile and recross with other hybrids as well as with one or both parents. Hybridization occurs between the pumpkinseed and the bluegill to such an extent that in some eastern Ontario lakes it is virtually impossible to designate true parental types. Hybridization in sunfishes was extensively studied by Hubbs and co-authors in the 1920's and 1930's and by Bailey and Lagler (1938). *See* the latter for various literature references.

Relation to man It would not be an exaggeration to say that the capture of this sunfish has probably delighted more children than that of any other Canadian freshwater fish. They occur in large numbers in shallow, sheltered situations, close to shore, attack even small pieces of live bait viciously, and fight strongly if erratically. Because of their size, they are usually ignored by the adult angler. Their flesh is white, flaky, sweet, and delicious. On light tackle with flies, "bugs," or poppers they can provide considerable sport and may be readily available when and where larger fish are not. There are usually no regulations covering size or bag limits for this species.

In some areas of Ontario and Quebec the pumpkinseed constitutes a commercial fish of some importance. They are usually caught in hoopnets set in the shallows. The catches of this species and the bluegill are recorded and marketed together in Ontario as sunfishes. In 1966, the total catch there was 253,015 pounds, worth nearly $29,000. The major producers in order of production were: Lake Ontario, southern inland lakes, Lake St. Clair, and Lake Erie.

Nomenclature

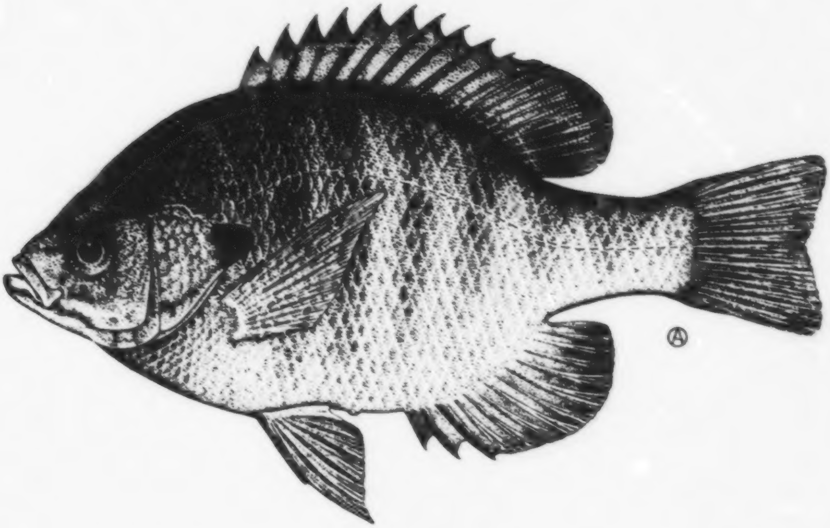
Perca gibbosa — Linnaeus 1758: 292 (type locality the Carolinas)
Pomotis vulgaris — Richardson 1836: 24
Lepomis gibbosus — Kendall 1895: 48
Lepomus gibbosus — Cox 1896b: 70
Eupomotis gibbosus (Linnaeus) — Jordan and Evermann 1896–1900: 1009
Lepomis gibbosus Jordan and Gilbert — Bean 1903b: 483
Lepomis gibbosus (Linnaeus) — Hubbs and Lagler 1939: 34

Etymology *Lepomis* — scaled operculum; *gibbosus* — gibbous, or like a full moon, referring to body shape.

Common names Pumpkinseed, pumpkinseed sunfish, yellow sunfish, common sunfish, sunfish, sunny, punky, sun bass, pond perch. French common name: *crapet-soleil.*

BLUEGILL

Lepomis macrochirus Rafinesque



Description This, the largest but second most common sunfish (other than the basses) in Canada, has a very deep, compressed body and individuals are usually 7–8 inches (178–203 mm) in length. Greatest depth, at third dorsal spine, 29.4–37.4% of total length; angle from snout to dorsal fin moderately steep, back rounded under dorsal fin; caudal peduncle rather long and narrow, its depth about 12% of total length. Head deep, moderately long, length 24.7–26.8% of total length, head narrow, angle of dorsal surface moderately steep, slight notch in dorsal surface before, and often behind, eye, head bluntly pointed; opercular flap rather long and deep, bone extends almost to tip and is fimbriate, but flap quite flexible over much of its length, totally black with no pale or coloured margin or spots; eye rather large, diameter 26.9–35.7% of head length, ahead and above centre of head; snout rather long, 20–25% of head length; mouth terminal, slightly oblique, rather small, lower jaw a little longer than upper jaw, lips prominent, gape reaching to anterior nostril, maxillary rather short, 26.3–31.6% of head length, reaching almost to anterior edge of eye; brushlike teeth present on jaws and vomer, lower pharyngeal teeth on longer, narrower pad than pumpkinseed, are numerous, conical and bluntly pointed. Gill rakers moderately long, slender, blunt, usually 12 on lower limb, and 4 on upper limb. Branchiostegal rays usually 6, rarely 6 and 5. Fins: dorsals 2, but broadly joined and appear as one, base of dorsal fins about 40% of total length and twice the length of the anal base, first dorsal fin long, spiny, moderately high, usually 10 but rarely 11 spines, edge rounded, length of last spine almost equal to height of second dorsal; second dorsal fin soft rayed, very little higher than first dorsal, base a little less than ⅔ base of first dorsal, rays usually 11, but frequently 10–12, edge rounded; caudal moderately broad, shallowly forked, tips rounded points; anal with moderately long base, about 20% of total length, about ½ dorsal base, 3 graduated, sharp spines and usually 11 rays, rarely 8–10, base of spiny part ⅓ that of soft part and third spine about ⅘ height of soft part of anal fin; pelvics thoracic, origin under second dorsal spine, base with broad membranous connection to abdomen, 1 small spine and 5 rays, fin rather long, overlaps anal origin, moderately broad, tip pointed to produced, edge square; pectorals moderately high on body, rather long, length 20.7–24.7% of total length, edge square to slightly round, tip pointed, usually 13, but rarely 14 rays. Scales mostly ctenoid, rather small, less crowded except on breast than in some sunfishes (*see* Potter 1925, for detailed discussion of scales of this species); lateral line complete, high except on peduncle, long, shallow arch over pectoral fin, 40–44 lateral line scales. Peritoneum silvery, intestine well differentiated, usually 6 prominent caeca. Vertebrae usually 28 or 29.

No nuptial tubercles but colour intensifies in breeding males. At other times sexes can be differentiated externally by the nature of the urogenital opening (McComish 1968).

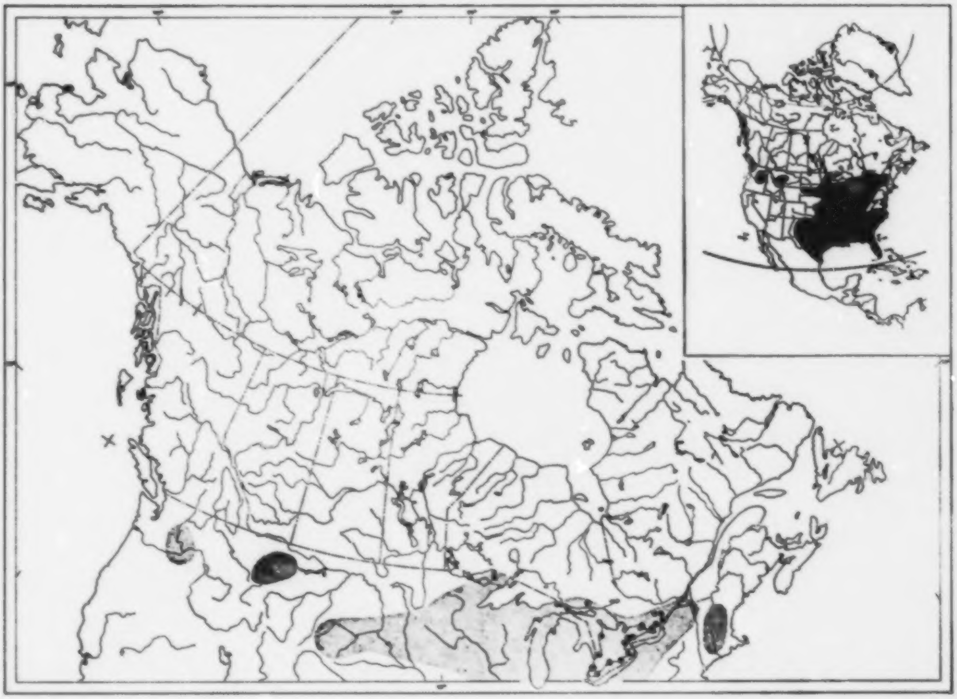
Colour Dorsal surface green, olive to almost brown, with several vague vertical bands extending down sides; upper sides brown to green, shading into brown, orange or pink; lower sides and abdomen behind pelvic fins, silver to white; breast yellow in females and in males most of year, copper-orange in males during breeding season; sides of head brown to green with metallic green and blue overtones, especially on ventral edges of opercular bones; opercular flap black only, often iridescent blue at anterior edge; all fins except pectorals with some black on lower parts of membranes, several membranes at posterior base of second dorsal blending into prominent rounded patch as big as, or bigger than, the eye, often white on leading edge of pelvic and anal fins, pectoral fins usually transparent yellow or amber. *See* colour illustration facing p. 442 for colours of breeding males.

Systematic notes Canadian populations are often listed as part of a northern subspecies, the common bluegill *L. m. macrochirus*, which is considered to intergrade in Arkansas with a form *L. m. speciosus* of Texas and Mexico. Another form, *L. m. purpurascens*, which may be a separate species, is thought to be present in the Atlantic coast streams from Virginia to Florida (Hubbs and Lagler 1964).

Distribution The native range of the bluegill is restricted to the fresh waters of eastern and central North America. It occurs south from the St. Lawrence River west of the Appalachian Mountains to the region of Chattahoochee River in Georgia. A form, usually called *L. m. purpurascens*, occurs in coastal rivers from Virginia to Florida. From Georgia it extends west to Texas and south into northeastern Mexico, north along a line from eastern New Mexico to eastern Minnesota and western Ontario, east, south of Lake Superior, to southern Ontario and Quebec, and into western New York. It has been introduced almost everywhere east and west of this area and definitely in Connecticut, Washington, Montana, Utah, Wyoming, and California. It has been introduced into Africa and possibly other areas off the North American continent.

In Canada it occurs in Quebec, in the upper St. Lawrence, Richelieu–Champlain, and Ottawa systems, generally through all of southern Ontario including the lower Great Lakes, but more abundant in eastern Ontario, absent west in Ontario to the lakehead, but present in the Quetico–Rainy River section of the Nelson River–Hudson Bay drainage. It is probably best known, most abundant, and larger in the Rideau Lake system of eastern Ontario.

Biology There is no detailed account of the life history of a Canadian population of this species. Spawning takes place in late spring to early and mid-summer in Canada, with the peak of activity probably in early July. Spawning in various locations in the



United States is described in detail by Breder (1936b), Carbine (1939), and summarized by Breder and Rosen (1966). Winter aggregations break up when water temperature reaches 50° F (10° C). The males appear first in the shallow water of spawning areas, become aggressive, territorial, begin nest building, and then the females appear. Nesting is colonial, with as many as 30 nests crowded into 160 square feet of suitable territory, in about 2.5 feet (814 mm) of water. By rigorous fanning with the fins the male clears an area, often 18–24 inches in diameter, making a shallow depression down to a firm bottom of gravel, sand, or mud. The same nest may be used by one or more males, with one or more females, over a spawning period extending as late as August with water temperatures as high as 76° F (24.5° C). The male defends the nest, before and after spawning, against all species but most vigorously against other male sunfishes. Many intermittent periods of spawning take place. Prior to spawning the parents swim about the nest in a circular path. They eventually come to rest with the male upright and the female at a 45° angle with their ventral surfaces touching. A few eggs and some milt are released and the pattern begins again. Egg number varies greatly with size of female. Mayhew (1956) estimated egg number for females 5.5–7.2 inches (140–183 mm) standard length and 142–269 g weight, to range from 7200 to 38,184. The eggs are small, amber in colour, demersal, and adhesive. Hatching takes place in approximately 3–5 days. Several females usually spawn in one nest and hatching success is high, since it has been determined that the number of fry resulting from a single nest can be from 4670 to 224 900. Obviously mortality rate of fry and young is correspondingly high. The nesting male probably guards the newly hatched young for a short period. Newly hatched fry are 2–3 mm in length.

Growth is rapid and Trautman (1957) said that young-of-the-year in Ohio were 0.7–3.2 inches (18–81 mm) long. Validation of the scale method of determining age and growth in this species was summarized by Regier (1962). There is no available analysis of age and growth in a Canadian population. That given in the following table for Michigan lakes by Beckman (1949) and for eight northern Wisconsin lakes by Snow (1969) may be slightly higher than the probable relation in Canada.

TTL

	Michigan lakes		Wisconsin 8 northern lakes	
Age	(*inches*)	(*mm*)	(*inches*)	(*mm*)
0+	1.7	43	–	–
1+	3.1	79	1.5	38
2+	4.3	109	3.1	79
3+	5.4	137	4.3	109
4+	6.6	168	5.6	142
5+	7.3	185	6.5	165
6+	7.7	196	7.2	183
7+	8.2	208	7.9	201
8+	8.4	213	8.0	203
9+	8.7	221	8.3	211
10+	8.9	226	–	–

In the Wisconsin data, length was given as completed years growth i.e., read age "n+" as "n".

This species sometimes attains lengths of 10–12 inches (254–305 mm) in the Rideau River system connecting the St. Lawrence and Ottawa rivers in eastern Canada. Elsewhere in Canada it often does not exceed 6–8 inches (152–203 mm) in length. This is the only species of the smaller sunfishes for which angling records are kept. The present record is one 15 inches (381 mm) long and 18¼ inches (463 mm) in girth which weighed 4 pounds 12 ounces, and was caught in Ketona Lake, Ala., in 1950.

Trautman (1957) gave maximum size in Ohio as 11.8 inches (300 mm) in length and 1 pound 3 ounces in weight. Maximum age would appear to be 8–10 years. Sexual maturity in Canada is probably attained by age 2 or 3 for males and 3 or 4 for females.

The bluegill inhabits the shallow, weedy, warm water of large and small lakes, ponds, and the heavily vegetated, slowly flowing areas of small rivers and large creeks. Groups of them retreat to deeper water in winter where they congregate in colonies but continue feeding. In summer they utilize small territories, move little, and an individual can be observed in the same place for hours. In the hottest periods of summer the largest individuals may move down as deep as 20 feet (610 m).

The food of this species is generally considered to be insects, crustaceans, and plant material. Keast and Webb (1966) considered the bluegill the most generalized feeder in Lake Opinicon (Rideau system) since up to 9 types of food formed 5% or more of its diet and it fed on the surface, in the water mass, and off the bottom. Only proportion and not composition varied with size, age, and season. The major foods of this species in Lake Opinicon were chironomid larvae (to 50% of the food volume of any individual), Cladocera (30%), amphipods and isopods (10%), flying insects (35%), Odonata nymphs (20%), Ephemeroptera nymphs (10%), Trichoptera larvae (15%), molluscs (15%), fish fry (10%). Small quantities of ostracods, copepods, and algae were also present. Keast and Welsh (1968) gave details on feeding times and rate of uptake of food in Lake Opinicon. Moffett and Hunt (1943) gave details on winter food. In other areas, plant material constituted as high as 22% of the diet of larger bluegills in late summer when insects were not as abundant. An argument has long been waged about the role of ingested plants and the ability of this species to derive nutrition from them. Kitchell and Windell (1970) showed that fish fed algae alone lost less weight than unfed fishes, those fed algae and animal protein gained weight faster than those fed animal protein alone. They determined that a 30-g bluegill would have to consume an amount of the algae *Chara* comparable to 5.5–5.9% of body weight per day to support maintenance alone.

Keast and Welsh (1968) described details of food uptake and dietary changes in this species. Keast (1968b) described feeding in winter.

The young and smaller adults of the bluegill are common in the diet of a wide variety of predaceous fishes as is evidenced by their use as the prey species in pond cultures of largemouth bass and northern pike. In lakes containing large populations of bluegills, they can be serious competitors for bottom organisms with other fishes. It has been calculated that they often consume up to 6 times their own weight and seriously deplete the bottom fauna.

The parasites listed by Hoffman (1967) for this species, over the whole of its range, were as follows: protozoans (9), trematodes (56), cestodes (8), nematodes (11), acanthocephalans (5), leeches (6), molluscs (1), crustaceans (12). Parasites of this species in Lake Erie were listed by Bangham and Hunter (1939). One parasite seen regularly on this species is black-spot — the resting stage of a trematode, of which the belted kingfisher is the final host — which causes the development of small black spots on the skin. These are harmless to humans.

This species is known to hybridize with the longear, orangespotted, green, redbreast, redear, and pumpkinseed sunfishes, and the warmouth. In many cases the hybrids are fertile and able to mate with both parents and with hybrids. The hybrid of this species and the pumpkinseed occurs virtually wherever these two live together in Canada. The degree of hybridization is so great and the range of characters so confusing as to make it almost impossible to separate hybrids from backcrosses with parental species, or even to designate pure parental forms.

Relation to man The bluegill is enjoyable simply as an active, colourful, and obvious part of the life of our fresh waters. They are inquisitive, fearless fish which come readily to the surface, or near the shore, to be fed with crumbs or oatmeal. They test the edibility of everything on or in the water, such as floating debris and even bathers' toes or fingers. Because of their colour, activity, and habitat the bluegill and the pumpkinseed are more often seen, recognized, and enjoyed by large numbers of people than any other species. They might almost be called free-living "ornamental" fishes. They are also sport fish and commercial fish but less so in Canada than in the central United States where they constitute one of the main sport fishes. The combination of very light fly rod, wet flies, dry fles, small poppers or "bugs," and bluegills are an angling delight. They attack the bait in groups, bite hard and fight hard. A large bluegill on a fly, pressing its deep body in a circular path, is hard for a fly fisherman to control. They can provide considerable enjoyment for young anglers using a small hook and small pieces of live bait. Bluegills are marketed usually by fishermen who set hoopnets in the shallows of lakes and rivers in Ontario and Quebec. They are marketed, with the pumpkinseed, simply as sunfish. The combined catch in Ontario in 1966, was 253,015 pounds with a value of nearly $28,812.48. The fishing grounds in descending order of catch in that year were: Lake Ontario, southern inland lakes, Lake St. Clair, and Lake Erie. The flesh is white, flaky, sweet, and delicious, but this species is most often ignored by Canadian anglers as a food fish.

The bluegill is one of the commonest forage fishes stocked with largemouth bass or northern pike in ponds and lakes managed for angling.

Nomenclature

Lepomis macrochira	— Rafinesque 1819: 420 (type locality Ohio River)
?*Lepiopomus pallidus* (Mit.) Gill and Jor.	— Jordan 1877a: 35
Lepomis Auritus	— Small 1883: 36
Lepomis pallidus (Mitchill)	— Jordan and Evermann 1896–1900: 1005
Helioperca incisor Cuvier and Valenciennes	— Hubbs 1926: 72
Helioperca incisor (Cuvier and Valenciennes)	— Hubbs and Greene 1928: 392

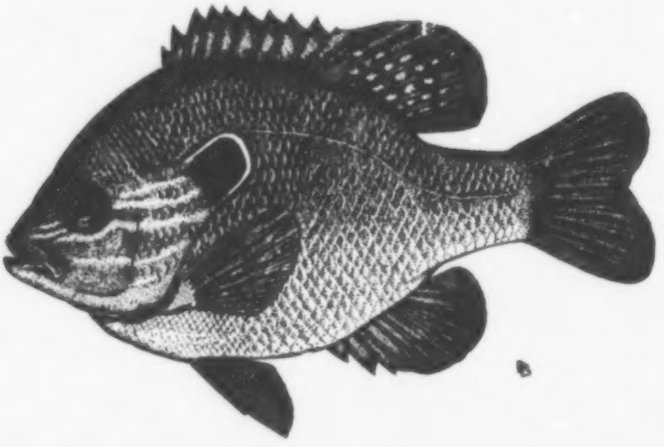
Helioperca macrochira (Rafinesque) — Dymond 1939: 39
Lepomis macrochirus macrochirus Rafinesque — Hubbs and Lagler 1941: 79
Lepomis macrochirus — Radforth 1944: 61

Etymology *Lepomis* — scaled operculum; *macrochirus* — large hand, possibly in reference to body shape.

Common names Bluegill, blue-gill, bluegill sunfish, northern bluegill sunfish, common bluegill, blue sunfish, sunfish, bream, blue bream, bluegill bream, roach. French common name: *crapet arlequin*.

LONGEAR SUNFISH

Lepomis megalotis (Rafinesque)



Description A very deep-bodied, laterally compressed, usually short fish; individuals in Canada usually only 3–6 inches (76–152 mm) in length; greatest depth at first to third dorsal spine, usually 31.4–41.5% of total length, greater in some populations and in smaller individuals, angle from snout to dorsal fin rather steep, back flat to rounded, caudal peduncle moderately deep. Head deep, moderately long, 27.5–32.2% of total length, head narrow, dorsal angle rather steep, depression over eye in males, often absent in females; opercular flap long, wide, turned-up, black, with pale red to yellow margin particularly at tip and along ventral edge, bone extends to near edge and is crenate, but flap flexible; eye diameter 25.0–38.5% of head length, eye well ahead and above centre of head; snout moderately short; mouth terminal, slightly oblique, moderately large, jaws equal, gape reaching posterior nostril maxillary reaching to, or just past, anterior edge of eye, length 29.4–39.3% of head length; many fine teeth on jaws, teeth absent from palatines, lower pharyngeal pad narrow, teeth less numerous, short, and pointed. Gill rakers moderately short, thick, and blunt, usually 12 on lower limb, 5 on upper limb. Branchiostegal rays usually 6 but at times 6 and 7, or 7. Fins: dorsals 2, but broadly joined and appear as 1, base of dorsal fin greater than twice anal base, base of first dorsal fin little longer than that of second, first dorsal with 10 or 11, rather low, even spines, last spine less than ½ height of second dorsal fin, second dorsal higher, almost as long, edge rounded, 10–12, usually 11, soft rays; caudal broad, well forked, tips round; anal base less than ½ that of dorsal, 3 graduated, but rather short spines and 10–12, usually 10, soft rays, base of soft portion almost as long as second dorsal, not high and quite rounded; pelvics thoracic, origin under second dorsal spine, length overlaps origin of anal fin, 1 small spine and 5 rays, edge square to rounded, tip pointed; pectorals rather high, short, length 16.4–23.4% of total length, and round, 10–13 rays, usually 12. Scales mostly ctenoid, rather small, crowded on nape and breast; lateral line complete, very shallow arch under dorsal fins, 33–38, usually 35, lateral line scales. Peritoneum silvery, intestine well differentiated, usually 7 prominent pyloric caeca. Vertebrae 28–30, usually 29.

No nuptial tubercles, pattern and colours considerably intensified in breeding males. Young with much smaller opercular flap and much less colour.

Colour Body usually highly colourful, upper surface olive to rusty brown, sides of body and head spotted or mottled with orange and emerald to turquoise, 8–10 vertical bars conspicuous to absent, cheeks orange, with wavy blue streaks or bars radiating back from mouth and eye, breast and ventral surface of body pale red, orange to yellow, fins other than pectorals brownish to orange, with some black pigment near bases of membranes, pectoral fins clear to dusky. The ear flap is usually long, wide, turned up, and black, edged with pale red to yellow, at least in adults.

Systematic notes The Canadian populations are usually included within the form *L. megalotis peltastes* Cope. Its counterpart, *L. m. megalotis*, occupies the southeastern area of the distribution of the species. The two were said by Trautman (1957) to intergrade along the Lake Erie–Ohio River divide. Other subspecies such as *breviceps* and *haplognathus* have been described from other parts of the range. Gruchy and Scott (1966) suggested the number of diagonal scale rows from the origin of the anal fin to the lateral line was lower (average 12.2) in specimens from northwest Ontario, than that given for the species farther south (14).

There appears to be little variation over its limited Canadian range. Material examined yielded lateral line scale counts of 33–37, but Legendre (1954) listed 33–39 for Quebec, and American authors listed 36–45.

Distribution This sunfish is restricted to the fresh waters of east-central North America. It occurs from southern Quebec south, west of the Appalachian Mountains, to the Gulf coast in Alabama. Moore (1968) included the east coast as far north as South Carolina. It extends west through eastern Texas and the Rio Grande tributaries in northeast Mexico, north through the eastern parts of the states from Oklahoma to central Minnesota, and in western Ontario; east, south of Lake Superior, through Wisconsin, Michigan, part of southern Ontario and Quebec, and into western New York. Less widely introduced outside its native range than most other sunfishes.

In Canada the longear sunfish occurs in the extreme upper St. Lawrence River system in Quebec, absent southwest to Ontario tributaries of central Lake Erie, occurs in tributaries of Lake St. Clair, Lake Huron, and Georgian Bay north to near the French River. Its presence in Ontario west of Lake Superior was unknown until reported by Gruchy and Scott (1966). It has since been taken in several more localities in Quetico Park in the Hudson Bay watershed. The populations in western Ontario are apparently isolated by some distance from the nearest populations in Minnesota. Possible explanations for this isolation were given by Gruchy and Scott.

Apparently the first authentic Canadian records of this species were those from tributaries of lakes Erie, St. Clair, and Huron by Hubbs and Brown (1929). Previous listings in Canadian works were on the basis of United States records for southern tributaries of the Great Lakes.

Biology Nothing is known of the biology of this species in Canada. Spawning habits were summarized by Breder and Rosen (1966) and those of the southern form were given by Witt and Marzolf (1954). Spawning probably takes place from late June to August, when water temperatures are 74°–77° F (23.4°–25.0° C). The males build saucer-shaped nests in gravel if available but otherwise in sand or hard mud. The nests are about 18 inches (457 mm) in diameter, close together, and in about a foot (305 mm) of water. The males are very territorial, aggressive, (*see* Huck and Gunning 1967) and defend nest, eggs, and young against much larger fishes, particularly bottom-swimming species. The circular swimming, vibrations, the vertical position of the male and 45° position of the female during the brief, intermittent spawning acts is typical of the family. The eggs are 1 mm in diameter, demersal, adhesive, amber to pale yellow in colour, and from 2360 to 22,119 in number for females 2–4 years of age. The male fans and guards the eggs during the 3–5 days they take to hatch. He also guards the tiny young for a few days. In Ohio the young-of-the-year in October were 0.8–1.8 inches (20–46 mm) in length (Trautman 1957).

There are no available growth rates for Canadian populations. Those given by Hubbs and Cooper (1935) for a 110–150 day growing season in Michigan probably approximate growth in Canada.

	TL	
Age	(*inches*)	(*mm*)
0+	0.9	23
1+	2.2	56
2+	2.9	74
3+	3.9	99
4+	4.5	114
5+	5.5	140
6+	5.5	140

Sexual maturity is probably attained at 2–4 years of age, and by males before females. Trautman (1957) gave maximum length in Ohio as 4.8 inches (122 mm) and a weight of 2 ounces. The largest individual taken in Canada was 5.9 inches (150 mm) long. Maximum age is probably 8 years. Many authors claim there is considerable dwarfing of this species in the northern part of its range. This species is very small in Canada but large population size cannot be the cause of dwarfing here, if it is such.

The locations from which this species has been taken in Canada vary from moderate-sized, shallow rivers, to ponds, to small lakes. Longear sunfish are usually found in shallow, clear, nearly still, moderately warm water, in or near areas of aquatic vegetation.

This species apparently feeds more extensively at the surface of the water than do some other sunfishes, and mature insects constitute a large percentage of their food. Insects in general and other invertebrates are the main food items. However, some authors record small fishes as a minor part of its diet.

The longear sunfish is nowhere abundant enough in Canada to form either a serious competitor of, nor a prominent food of, other fishes.

Parasites listed for this species, over the whole of its range, by Hoffman (1967) were: protozoans (1), trematodes (17), cestodes (2), nematodes (2), acanthocephalans (2), and crustaceans (2). In Canada it no doubt carries black-spot, the resting stage of trematodes so common in other sunfishes, which is harmless to man.

Bangham and Hunter (1939), listing parasites of fishes of Lake Erie, gave only cysts of *Neascus vancleavei* for this species.

The longear sunfish is known to hybridize in nature with the bluegill, green, and orange-spotted sunfishes.

Relation to man This sunfish is too small, and not abundant enough in Canada to be of any economic importance. The true extent of its distribution in Ontario has only been known for a few years. It is, however, one of the most colourful and attractive freshwater fishes that we have. Its size, bright colour, and still-water habitat would make it a very pleasing aquarium species.

Nomenclature

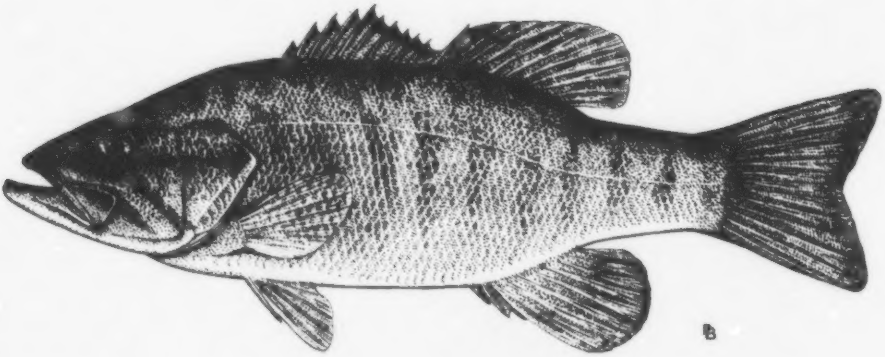
Icthelis megalotis	— Rafinesque 1820b: 49 (type locality Licking and Sandy rivers, Ky.)
Lepomis megalotis Rafinesque	— Halkett 1913: 82
Lepomis megalotis (Rafinesque)	— Dymond 1922: 69
Xenotis megalotis peltastes Cope	— Hubbs 1926: 72
Lepomis megalotis peltastes Cope	— Hubbs and Lagler 1941: 79
Lepomis megalotis	— Radforth 1944: 61

Etymology *Lepomis* — scaled operculum; *megalotis* — great ear, in reference to long, wide opercular flap.

Common names Longear sunfish, long ear or long-eared sunfish, northern longear, Great Lakes longear. French common name: *crapet à longues oreilles*.

SMALLMOUTH BASS

Micropterus dolomieui Lacépède



Description A moderately large and robust fish, in the family only the largemouth is larger; body laterally compressed, less so than other sunfishes, cross section a narrow oval. Most individuals seen in Canada are 8–15 inches (203–381 mm) in length. The following percentages and counts are for individuals from Ontario and Quebec. Greatest depth, at origin to middle of first dorsal fin, 20.3–28.2% of total length; angle from snout to back low, back flat to rounded; caudal peduncle long and rather deep. Head large, long, 26.6–30.5% of total length, deep, moderately wide, dorsal surface rounded or with a shallow depression over the eyes, operculum bony to edge, pointed but not extended into a flap, usually a vague black spot near its tip; eye large, its diameter 14.1–30.0% of head length, larger in young; snout long, its length about 35% of head length, deep, bluntly pointed, scales on cheek in diagonal row, from eye downward 14–18 (9 or 10 in largemouth bass); mouth terminal, slightly oblique, lower jaw slightly longer than upper, gape reaching to near front of eye; maxillary long, 40.0–46.7% of head length, but usually reaching just to middle of eye (beyond eye in largemouth bass), posterior edge rounded; fine, brushlike teeth on both jaws, palatines, and vomer; lower pharyngeal teeth on long, narrow pad, numerous, fine, uniform in size. Gill rakers usually 8 on lower limb and 3 on upper limb. Branchiostegal rays 6, 6 and 7, or 7. Fins: dorsals 2, but joined and appear more like one than do those of largemouth bass, first dorsal rather low, with 10 stout spines not markedly different in length, the last appearing to be part of second dorsal; separation between dorsal fins not deep, shortest posterior spine longer than ½ length of longest spine; second dorsal higher, 12–15 soft rays, edge rounded; caudal not markedly long but broad, moderately forked, tips blunt points to rounded; anal with base less than that of second dorsal fin, 3 graduated spines and 10–12 (usually 11) soft rays, edge rounded; pelvics thoracic, origin ahead of origin of dorsal fin, joined by membrane (not so in largemouth bass), less conspicuously joined to body by membrane than in largemouth bass, pelvics not long, 1 spine and 5 rays, tip rounded; pectorals not long, but broad and rounded, 13–15 rays. Scales ctenoid, slightly smaller than in largemouth bass, usually 11–13 rows from lateral line to dorsal origin and 19–23 rows from lateral line to anal origin, a few minute scales on membranes of dorsal and anal fins; lateral line complete, high and little arched, 68–78 lateral line scales. Peritoneum silvery, intestine well differentiated, 7–10 thicker pyloric caeca, few if any branched. Vertebrae 31 or 32.

No nuptial tubercles but colours darken on spawning males and colour pattern of females intensifies.

Colour Variable with size, condition and habitat. In clear, vegetated water or stained water they are darker with pronounced, contrasting markings, in turbid water lighter with vague markings; dorsal surface of back and head brown, golden brown through olive to green, sides lighter, more golden with golden flecks on most scales, ventral surface cream to milk-white; sides of adults with 8–15, pronounced to vague, thin, vertical bars, sometimes broken; head with dark bars radiating backwards from eyes, eye usually red or orange; fins dusky to amber, pectorals clear, others opaque with some black on rays, spines, or membranes.

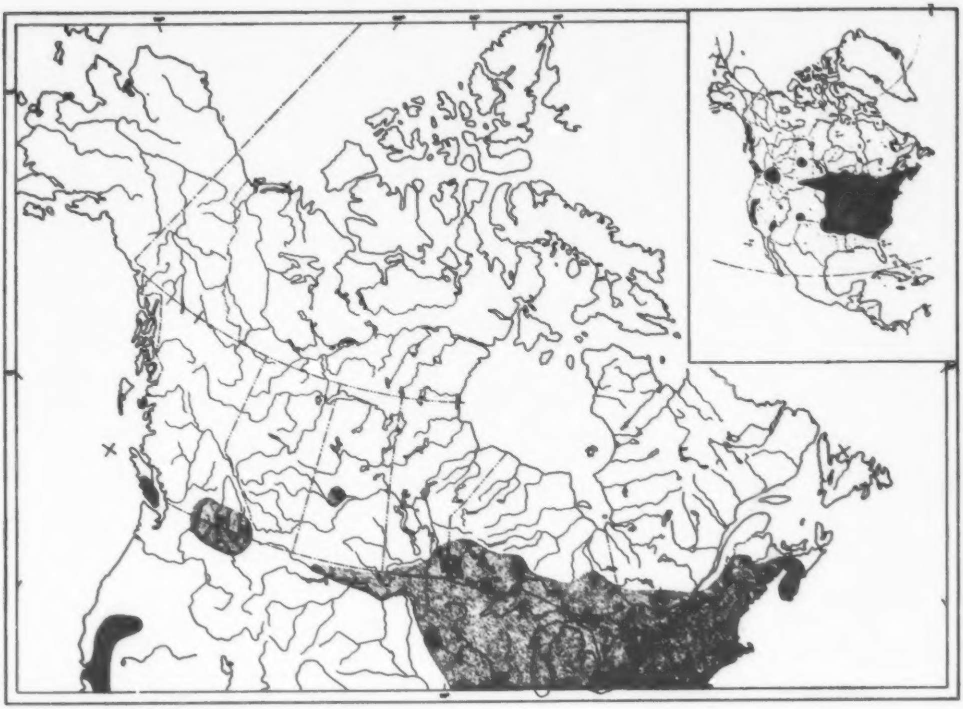
Young much like adults but vertical bars or rows of spots very prominent and caudal fin unmistakably marked orange at base, followed by a black band, and white to yellow tips. *See* colour illustration facing p. 730.

Systematic notes Canadian populations often included in a subspecies *M. d. dolomieui*, and southwestern populations are designated *M. d. velox*. The extent of introduction and artificial culture of this fish would now make it virtually impossible to detect morphometric trends in Canadian populations.

Distribution Originally the smallmouth bass was restricted to the fresh waters of eastern central North America. Its range was expanded starting in the mid-1800's until now it occurs almost everywhere in the United States, many places in England, Europe, Russia, and Africa. Its original range was limited to the Great Lakes–St. Lawrence system (apparently excluding Lake Nipigon but including nearby lakes tributary to the Nipigon River and the north shore of Lake Superior, Dymond 1926) and the systems of the Ohio, Tennessee, and upper Mississippi rivers (white line on inset map, from Hubbs and Bailey 1938). It now occurs generally from Nova Scotia south to Georgia and eastern Alabama, west to northeastern Oklahoma, north, through eastern Kansas to Minnesota, west through North Dakota, in central Saskatchewan, east from southern Manitoba to Quebec and Maine.

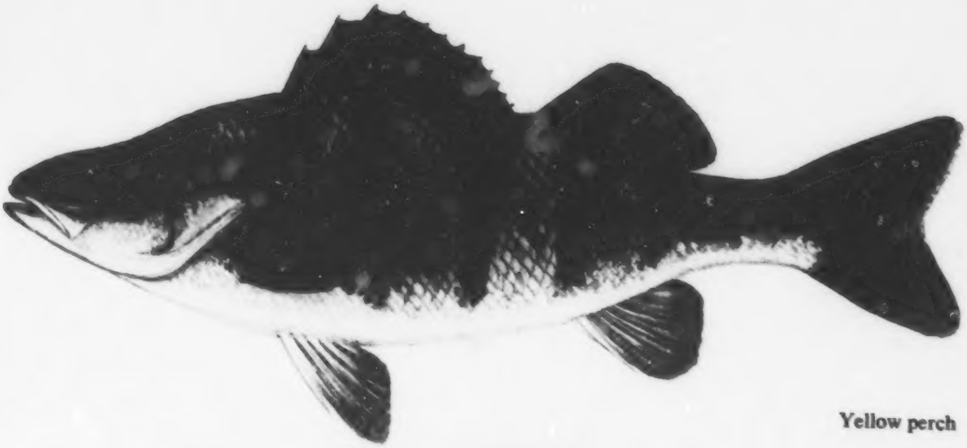
In Canada it occurs in lakes in southern Nova Scotia, southern and western New Brunswick, southern Quebec from Hull upstream in the St. Lawrence River and its tributaries, throughout the eastern townships including Lake Champlain, the Gatineau River, and the Ottawa River system as far north as Temiskaming; through Ontario approximately at the latitude of Timmins and Lake Nipigon (absent from that lake), Manitoba north to the south end of Lake Winnipeg, and in central Saskatchewan. It occurs in eastern British Columbia in lakes of the Columbia River system, and on Saltspring Island and southern Vancouver Island as a result of invasion from introductions in Washington State and by direct introduction. Dates of first Canadian introductions beyond the natural range are: Nova Scotia 1908 (Catt 1949), New Brunswick 1894 and 1901 (Cox 1896b; Dom. Dep. Fish. 1902), Ontario 1901 (MacKay 1963), Manitoba 1900–1942, Saskatchewan 1900–1942, Alberta early 1900's (failed) (Rawson 1945), British Columbia 1901 (Dymond 1936).

Biology Contrary to the case for many Canadian fishes, published information on the biology of the smallmouth bass in Canada is very extensive and dates from 1876. Some of these publications are Wilmot (1876), Loudon (1910), Bensley (1915), Tester (1930), Dymond (1931a), Tester (1932a, b), Rawson (1938), Doan (1939, 1940), Smith (1942), Fraser (1955), Fry and Watt (1957), Rowan (1962), Coble (1967), Turner and MacCrimmon (1970), and several unpublished manuscripts in the Great Lakes Library, Department of Zoology, University of Toronto, Toronto, Ont. A very extensive bibliography of the literature on this species exists in the Division of Research,



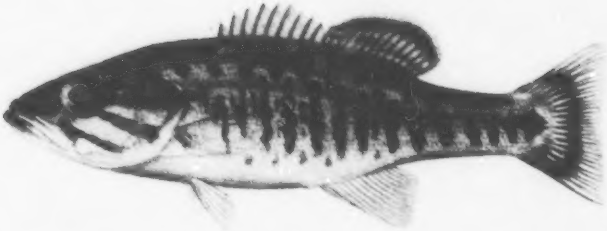
Ontario Department of Lands and Forests. The following information was derived from the works mentioned.

Smallmouth bass spawn, usually over a period of 6–10 days, in the late spring and early summer, most often late May to early July. Nest building and spawning (in some areas) commences over a range of temperatures 55°–68° F (12.8°–20.0° C) but egg deposition takes place mostly at 61°–65° F (16.1°–18.3° C). The male builds a nest 1–6 feet (30.5–183.0 cm) in diameter in 2–20 feet (61–610 cm) of water on a sandy, gravel, or rocky bottom, of lakes and rivers, usually near the protection of rocks, logs, or, more rarely, dense vegetation. Some males return to the same nest in subsequent years and over 85% of them return to within 150 yards of where they nested in previous years. After nest building, there is considerable prespawning activity, display, rubbing, and nipping. The male and female swim about the nest and eventually come to rest on the bottom, their ventral surfaces nearly in contact, with the male vertical and the female at a 45° angle. Actual egg deposition and fertilization takes place for about 5 seconds, and repeated acts take place for a period of about 2 hours with intervening periods of nest-circling lasting 25–45 seconds. Egg number in females, depending on size, apparently ranges from 5000 to 14,000 and is said to approximate 7000 per pound of female. They are light amber to pale yellow in colour, demersal, adhesive, and 1.2–2.5 mm in diameter. They are usually found attached to clean stones near the centre of the nest. After spawning, the female leaves the nest and may spawn in another nest with another male. The male guards the nest, fans the eggs, and guards the young after they hatch. Often 40% of the nests are failures and approximately 2000 fry result from most successful nests. Sudden shifts of temperature upward or downward, changes in water level, and fungal infections kill many eggs. The larger the female and

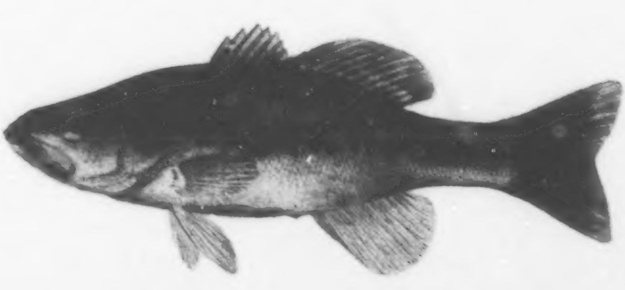


Yellow perch

Rainbow darter



Smallmouth bass



Largemouth bass

guarding male, the greater the hatching success. Hatching usually takes place in 4–10 days over the temperatures common in Canadian situations. The young at this time are 5.6–5.9 mm in length. In an additional 12 days the young have absorbed the yolk and rise off the bottom. At this time they are 8.7–9.9 mm in length. After 5–7 days, they begin to leave the nest but are still guarded by the male for several days. Reighard (1906), Fish (1932), and Doan (1939) gave details of eggs, embryology, and development of young.

Growth is rapid at first and in Lake Nipissing, near the northern limit of distribution, they are 32.2–36.6 mm in length by July and are 2–4 inches (51–102 mm) in length by decline of temperatures in the fall. In Lake Erie, growth of young is 0.8–0.9 mm per day. The age–length and age–weight relations in various Canadian habitats are shown in the following table.

Rowan (1962) gave experimental length–weight relation at 74° F (22.5° C), a temperature common in Canadian habitats, as Log W(g) = −3.1176 + 3.0699 Log L(FL mm). Growth of older fish is variable from place to place and year to year. Sexual maturity is usually attained by males in their third to fifth year and females in their fourth to sixth year. Females probably spawn every year. Many factors, including summer temperature, water levels, wind, nest desertion, predation, angling, and the bass tapeworm greatly affect reproduction and survival of young, resulting in large and small year classes with vastly different contributions to the population and harvest (Fry and Watt 1957; White 1970).

Maximum age in Canada would appear to be about 15 years. Maximum known size in Canada is probably either a female 13 years old, 23 inches (584 mm) in fork length, 17¼ inches (437 mm) in girth, 9 pounds 2 ounces in weight, captured by an angler in McCauley Lake, near Madawaska, Ont., in September, 1951, or one said to be 9 pounds 13 ounces that was caught in Birchbark Lake near Kinmount, Ont., in 1954. A record of 11 pounds in Canada is probably an error. Fish over 23 inches (584 mm) were more common in 1906–1936, but prize winning fish of 5–7 pounds are taken almost every year. Those most frequently caught by anglers, however, are 8–15 inches (203–381 mm) in length and usually not over 3 pounds. Some supposed "records" are based on misidentifications as possibly was the 20-pounder reported speared in Ashbridges Bay, Toronto, in 1842 (*Canadian Sportsman and Naturalist* 1882, 2(4): 122). Trautman (1957) recorded fish to 22.5 inches (572 mm), and 6 pounds 10 ounces in Ohio, and said maximum weights of 10–14 pounds had been recorded elsewhere. The present ***Field and Stream*** angler record is one 27 inches (686 mm) long, 21¾

		Age															
		0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+
Potter's L., N.B. (Smith 1942)	FL *inches*	1.5	4.9	7.8	9.6	10.9	11.9	12.8	13.5	–	–	–	–	–	–	–	–
	mm	38	124	198	244	277	302	325	343	–	–	–	–	–	–	–	–
	Wt *oz*	0.03	1.0	4.5	8.2	12.2	14.2	16.7	20.4	–	–	–	–	–	–	–	–
L. Erie, Ont. (Doan 1940)	TTL *inches*	–	–	–	6.5	9.9	10.5	12.5	13.6	14.8	15.6	–	–	–	–	–	–
	mm	–	–	–	165	251	267	318	345	376	396	–	–	–	–	–	–
	Wt *oz*	–	–	–	2.9	9.8	23.1	27.3	29.9	32.5	34.4	–	–	–	–	–	–
Baie du Doré, L. Huron, Ont. (White 1970)	FL *inches*	–	5.5	7.0	8.3	9.7	10.8	12.0	13.0	13.8	14.5	15.4	15.6	16.2	16.3	–	18.0
	mm	–	140	178	211	246	274	305	330	351	368	391	396	411	414	–	457
	Wt *oz*	–	–	1.9	3.8	8.2	12.5	17.8	24.6	34.1	34.9	36.8	37.6	–	–	–	–
L. Nipissing, Ont. (Tester 1932b)	FL *inches*	–	–	8.1	9.4	10.9	11.7	13.4	14.0	14.8	15.5	16.2	16.3	–	–	–	–
	mm	–	–	206	239	277	297	340	356	376	394	411	414	–	–	–	–
	Wt *oz*	–	–	6	8	13	17	25	28	34	40.5	43.5	56	–	–	–	–

inches (549 mm) in girth and 11 pounds 15 ounces, caught in Dale Hollow Lake, Ky., in 1955.

Habitat varies with size and time of year. In the spring, adult fish congregate on the spawning grounds. Later they are usually found in rocky and sandy areas of lakes and rivers, in moderately shallow water. In the heat of summer they usually retreat to greater depth. Usually they are to be found around the protection afforded by the rocks of shoals and talus slopes, or submerged logs. They are much less often associated with dense growths of aquatic vegetation than are largemouth bass and they prefer a lower temperature than that species. Final preferred temperatures under experimental and field conditions have been given as 82.4°F (28°C), and 68.5°–70.3° F (20.3°–21.3° C) respectively in Wisconsin (Ferguson 1958). Average summer temperatures of many Ontario bass habitats was 70.6°F (21.4°C). Diet and seasonal movements are partly in response to attempts to remain in the preferred temperature. Upper lethal temperature has been determined experimentally to be as high as 95° F (35° C), but it is usually considered that this species cannot stand high environmental temperatures as well as the largemouth bass. Most studies have shown that movements are usually limited to ½–5 miles from place of capture. However, bass tagged in the Chateauguay River, Que., migrated up and down the St. Lawrence River for distances up to 30 miles (Cuerrier 1943). There is evidence of homing to spawning ground and summer territory. Hallam (1959) gave extensive details on physical, chemical, and faunal characteristics of the habitat of this species. In winter, smallmouth bass aggregate near the bottom, are very inactive, eat little, and are rarely taken by anglers. They begin feeding in the spring when water temperature reaches 47.3° F (8.5° C) (Keast 1968b).

In general, the food of adults of this species consists of insects, crayfish, and fishes. The smallmouth bass takes this variety of food from the surface, in the water mass, and off the bottom. There is a progression with increase in size from plankton, to immature aquatic insects, to crayfish and fishes. The importance of various items within size groups shifts, with availability, from place to place. Tester (1932a) gave an extensive summary of the food from several Ontario habitats by season, size, and location. By 20 mm length, insects replace the previous plankton dominance and by 50 mm fishes and crayfish are the important items. For adults in most habitats, crayfish form approximately 60–90% of the food volume, fishes 10–30%, and aquatic and terrestrial insects 0–10%. Frogs, tadpoles, fish eggs, and plant material are often present as well. If any particular fish can be said to dominate, it is the yellow perch. This may, however, be a result of the ease with which they are identified. Most cyprinids are listed simply as unidentified. The following are among those which have been recorded: yellow perch, johnny darter, Iowa darter, log perch, northern pike, sculpins, sticklebacks, white sucker, bluntnose minnow, emerald shiner, spottail shiner, cyprinids, yellow walleye, white bass, freshwater drum, trout-perch, sunfishes, rockbass, ciscoes, and smallmouth bass.

Young smallmouth bass are probably eaten by many predators. Groups of rock bass, as predators, apparently cause a significant loss of eggs and fry. While the guarding male is chasing one rock bass the others feed in or over the nest. Other predator species mentioned are yellow perch, sunfishes, catfishes, gar pike, suckers, and turtles.

Competition for food involves interaction with a wide variety of fishes with similar habitat requirements, but does not seem to be a serious limiting factor. Competition for nesting areas seems to be exerted by rock bass and, in shallower nests, by sunfishes.

Parasites of this species over the whole of its range, listed by Hoffman (1967) were: protozoans (12), trematodes (49), cestodes (12), nematodes (13), acanthocephalans (9), leeches (9), molluscs (1), crustaceans (9). Parasites of this species from Lake Erie, Algonquin Park, Ont., and Lake Huron were listed by Bangham and Hunter (1939), Bangham and Venard (1946), and Bangham (1955). Of these parasites, three are of the most concern to man: the bass tapeworm *Proteocephalus ambloplitis*, which can cause sterility or seriously limit reproduction of this species, and black-spot and yellow grub which, when present, often deter anglers from eating their catch. None of these parasites is harmful to man.

The smallmouth bass is known to hybridize in nature with the spotted bass *M. punctulatus*.

Relation to man The magnitude and antiquity of interest in this bass is obvious in the fact that angling results were mentioned in Fothergill's 1816–1837 *Account of the natural history of eastern Canada* (Black 1934), that introductions in North America began in the 1850's, and fish culture practice in Canada in 1884. Rawson (1930a) summarized the history of the fishery in Lake Simcoe, Ont., from the time of Champlain to 1930. Smallmouth bass in Canada were taken by the ton by hook and line and by nets, at least until 1936. It sold for as little as 6–8¢/pound in 1898–1902. As early as 1893 complaints were made to the Dominion Fisheries Commission about the depletion in Lake Simcoe caused by the commercial catch. An International Anglers Commission meeting in Niagara Falls, Ont., in 1894 spoke of rapid extinction of the basses and recommended a closed season during spawning and prohibition of sale. After that, it was universally restricted as a sport fish and its capture is now controlled by season and bag limits.

Angler enjoyment, success, and harvest have been extensively studied (*see* Budd 1961).

Its attraction for anglers and its sporting quality are now almost legendary. That and techniques of its capture are the subject of many popular books and articles in sporting magazines. It suffices to say here that the smallmouth bass is still one of three or four fishes which are the mainstay of the gigantic sport fishery and associated tourist industries in eastern Canada. Good populations of bass still yield limit catches and, on average, 0.5–1.1 fish per man hour.

Smallmouth bass are usually taken still fishing with crayfish, minnows, or frogs as bait; by casting live bait, spinners, or plugs; by trolling live bait or artificial lures; or by fly fishing with wet or dry flies. The flesh of large or small individuals is white, flaky, and delicious when prepared in any of a variety of ways.

The most important areas of angler success for this species, Lake Erie, the Thousand Islands section of the St. Lawrence River, and Georgian Bay, are seriously threatened by domestic, industrial and possibly thermal pollution.

Nomenclature

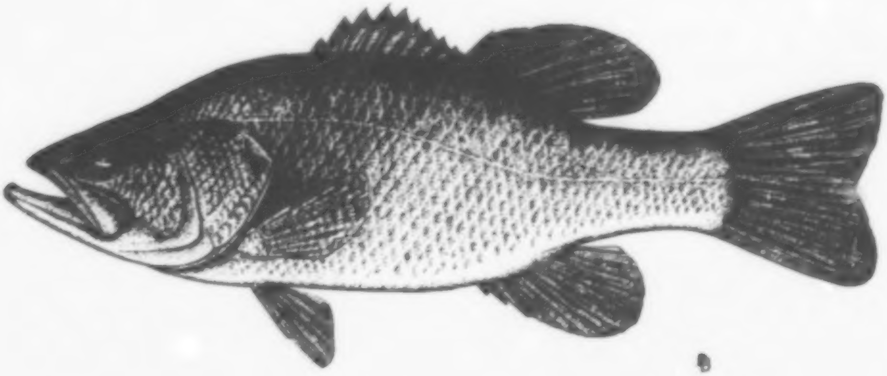
Micropterus dolomieu	— La Cepède 1802: 324 (type locality unknown)
Bodianus achigan	— Rafinesque 1817b: 120
Cichla fasciata	— LeSueur 1822a: 216
Cichla minima	— LeSueur 1822a: 220
Cichla fasciata (LeSueur)	— Richardson 1836: 23
Cichla minima (LeSueur)	— Richardson 1836: 24
Grystes nigrisans	— Forelle 1857: 278
Gristes nigricans	— Roosevelt 1884
Centrarchus fasciatus	— Small 1865: 19
Micropterus dolomieu dolomieu Lacépède	— Hubbs and Lagler 1941: 78
Micropterus dolomieui dolomieui Lacépède	— Hubbs and Lagler 1958: 113
Micropterus dolomieui Lacépède	— Scott 1967: 89

Etymology *Micropterus* — small or short fin, a damaged second dorsal led Lacépède to think there was a short fin at the rear of it; *dolomieui* — after M. Dolomieu, a French mineralogist and friend of Lacépède, after whom dolomite was named.

Common names Smallmouth bass (previously the hyphenated or unhyphenated combinations of the separate words small and mouth or mouthed with any or all of the following), northern smallmouth bass, smallmouth black bass, black bass, brown bass, green bass (more often used for largemouth bass), white or mountain trout, in the south. French common name: *achigan à petite bouche.*

LARGEMOUTH BASS

Micropterus salmoides (Lacépède)



Description A moderately large, robust fish, body less laterally compressed but deeper than the smallmouth bass, cross section a broad oval. Most individuals seen in Canada are 8–15 inches (203–381 mm) in length. The following percentages and counts are for bass from Ontario and Quebec. Greatest depth, under base of first dorsal fin, 20.9–29.7% of total length; angle from snout to dorsal fin low, back flat; caudal peduncle long and deep. Head large, long, 26.6–31.7% of total length, deep, wide, dorsal surface almost always with long, deep notch over the eyes; operculum bony to edge, pointed, not extended in a flap, usually a vague dark spot near tip; eye large, its diameter 12.8–20.5% of head length, larger in young; snout long 25–28% of head length, not deep as in smallmouth bass, bluntly pointed, scales on cheek, diagonal from eye, 9 or 10 (14–18 in smallmouth bass); mouth terminal, little oblique, large, wide, lower jaw slightly longer than upper, gape reaching to middle of eye; maxillary very long (less so in young), 45.7–54.3% of head length but reaching at least to posterior margin of eye in adults; posterior edge usually square; fine brushlike teeth on both jaws, palatines, and vomer; lower pharyngeal teeth on long, narrow pad, numerous, fine, uniform in size. Gill rakers usually stiffer, 6–8 on lower limb and 2 rudiments on upper limb. Branchiostegal rays 6, 6 and 7, or 7. Fins: dorsals 2, joined, but separation more obvious, first dorsal rather low, 10 stout spines, short front and rear, last spine appearing to be part of second dorsal; separation between dorsals deep, shortest posterior spine less than ½ height longest spine; second dorsal higher, 12 or 14 (usually 12) rays, rounded; caudal, not long but broad, shallowly forked, tips rounded; anal with base less than that of second dorsal, 3 spines and 10–12 (usually 11) soft rays, rounded; pelvics thoracic, origin under that of first dorsal fin, fins not joined by membrane but conspicuously joined to body by membrane, pelvics short, rounded, 1 spine and 5 soft rays; pectorals rather short, broad, tip rounded, 13–15 rays. Scales ctenoid, larger than smallmouth bass, usually about 8 rows from lateral line to dorsal origin and 14–18 rows from lateral line to anal origin, usually no scales on membranes of dorsal and anal fins; lateral line complete, high, little arched, 60–68 lateral line scales. Peritoneum silvery, intestine well differentiated, 24–28 thinner pyloric caeca, at least 6–10 branched. Vertebrae 30–32. Shufeldt (1900) gave osteological differences in largemouth and smallmouth basses.

No nuptial tubercles but colours darken on spawning males.

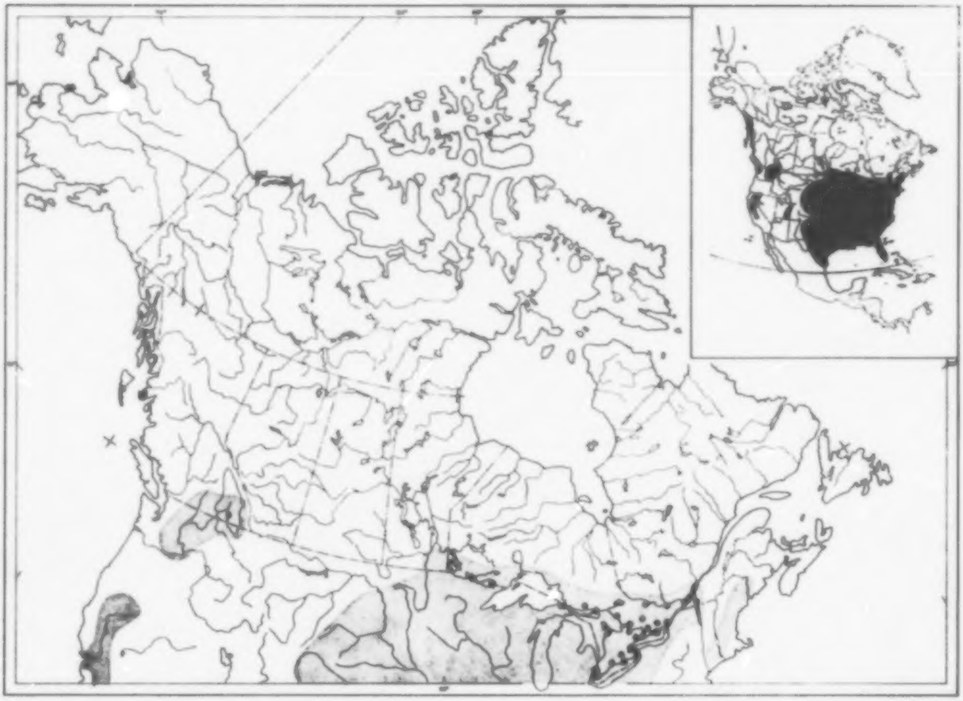
Colour Dorsal surface of body and head bright green to olive, sides almost as dark in largest, to lighter green or golden green, ventral surface milk-white to yellow, a pronounced wide, solid black lateral band sometimes continuous across opercle through eye to snout, particularly in young, broken or inconspicuous to absent in adults, sides of head olive to golden green with some scattered black pigment, inside of mouth milk-white, eye brownish, dorsal and caudal fins opaque, green to olive, anal and pelvic fins green to olive with some white, pectoral fins amber and clear. Populations in clear, weedy water darker and black pigment more obvious, those in darker or turbid water overall pale green. Caudal fin of young like that of adult, no bright colours. *See* colour illustration facing p. 730.

Systematic notes Canadian populations are often included as part of a subspecies, *M. s. salmoides*, the northern largemouth bass. The other form is *M. s. floridanus* in Florida. Meristics for populations in various localities north to south were given by Bailey and Hubbs (1949), Hart (1952) and Bryan (1969). Canadian material examined is insufficient to detect meristic or proportional differences in Canada.

Distribution The native range of this bass included the fresh waters of the lower Great Lakes, the central part of the Mississippi River system south to the Gulf Coast, Florida, and north on the Atlantic coast to Virginia. As a result of extensive introductions it now occurs over virtually the whole Atlantic coast (rarely into brackish water) from Maine to Florida, west to Texas and northeastern Mexico, north through the eastern parts of the states from New Mexico to North Dakota, and east across southern Canada to western New York. It occurs by introduction in isolated locations in almost the whole United States west of this, and has been introduced into such places as England, Scotland, Germany, France, South Africa, Hong Kong, the Philippines, and Brazil.

In Canada it occurs in the St. Lawrence River and its tributaries from Lac St. Pierre upstream, the Richelieu–Champlain system, the Ottawa system north to Temiskaming, west across the north shore of Lake Superior, but excluding that lake, to southeastern Manitoba. It was introduced in Saskatchewan in 1950 but failed. It occurs in southeastern British Columbia in several lakes in the Columbia River system to which it spread after its introduction in Idaho in 1916. It is probably commonest, most abundant, and best known in the Kawartha and Rideau lakes in Ontario. The overall range of this bass is almost equal to that of the smallmouth bass but it is common and abundant only in a much smaller, more southern area.

Biology There is much less published information on this species in Canada than on the smallmouth bass. *See* Bensley (1915), Curran et al. (1947), Hart (1952), Lewis (1965), Keast and Webb (1966), Johnson and McCrimmon (1967), supplemented by



information on populations in the northern United States given by Bennett (1954), Kramer and Smith (1960a, b, 1962), Mraz et al. (1961) and Mraz (1964b).

The largemouth bass spawns from late spring to mid-summer (sometimes as late as August) with the peak of spawning usually early to mid-June. Nest building by males usually begins within a few days of the time the mean water temperature reaches 60° F (15.6° C), but spawning usually takes place at 62°–65° F (16.7°–18.3° C). In water containing both largemouth and smallmouth basses, the largemouth will spawn a little sooner, because the shallower, protected spawning sites in quiet bays, among emergent vegetation, warm to the optimum temperature sooner than do the deeper, rockier, sites used by the smallmouth bass. Spawning grounds vary from gravelly sand (more rarely) to marl and soft mud in reeds, bullrushes, or water lilies. The very aggressive, territorial males sweep clean an area 2–3 feet (61.0–91.5 cm) in diameter and, depending on the hardness of the bottom, 1–8 inches (25–203 mm) deep, usually in 1–4 feet (30.5–122.0 cm) of water. Often the bottom of the nest includes the exposed roots of emergent vegetation. Nests are usually at least 30 feet (9.15 m) apart. The spawning behaviour is much like that of the smallmouth bass, involving nudging, nipping, parallel swimming, the vertical and 45° positions of male and female, and repeated spawnings separated by short intervals. A female may spawn with several males on different nests. *See* Reighard (1906) and Breder and Rosen (1966) for detailed account. Females probably spawn yearly between the ages of 5 and 12 years. Egg number per female varies with size and has been reported to be from 2000–109,314 per female or 2000–7000 per pound of female. The eggs are demersal, adhesive, amber to pale yellow in colour, and when fertilized are 1.5–1.7 mm in diameter (*see* Kelley 1962, for details of fecundity). Eggs are often laid over the whole of the bottom and lip of the nest, not as compactly as those of the smallmouth bass. Changes in water temperature, wind, waves, nest desertion, predation by rock bass, by other sunfishes, and by the guarding male himself, limit the success of the hatch. Apparently golden shiners and lake chubsuckers often spawn in active nests of this species which are being guarded by a male. The male guards and fans the eggs. Hatching takes 3–5 days at water temperatures prevalent in Canadian habitats. On hatching, the young are transparent and 3 mm long. The number of fry resulting from a single nest has been determined at 751–11,457, with an average of 5000–7000. They remain in the bottom of the nest until the yolk is absorbed, usually 6 or 7 days, then they rise, begin feeding and schooling. At this time they are 5.9–6.3 mm in length. They may remain in a brood as long as 31 days and are guarded over part or all of this time by the male. The young of this species are at this time a very pale green rather than the black of smallmouth bass. Reighard (1906), Fish (1932), and Carr (1942) gave details of eggs and early development of the young. Survival rate is low and usually only 5–10 live to reach 10 inches (254 mm) length.

Growth is rapid at first. Trautman (1957) said that young-of-the-year in October in Ohio were 2–5 inches (51–127 mm) in length. Availability of quantities of invertebrate food of appropriate size for fry rising off nests, and water temperature and its effect on rate of growth before mid-August of the first year seem to determine the ultimate growth history. (*See* Kramer and Smith 1960b, for details of growth in first year in Minnesota). Spawning success, growth, and survival in the first year determine strength of the year-classes. As in smallmouth bass, good and poor year-classes make strikingly different contributions to the population and angler harvest. Growth is extremely variable but that in Ontario does not fall behind that in the northern United States. The following table gives the age–length and age–weight relations of a population in Lake Opinicon (St. Lawrence–Ottawa system), Lake Simcoe (Great Lakes system), and a generalized average for Ontario.

Lewis (1965) gave the length–weight conversion as Log W (in pounds) = –3.8384 + 3.4859, Log TL (in inches). Present known maximum size in Canada is an individual of 14 pounds 12 ounces caught in Stoney Lake, Peterborough Co., Ont., in 1948. Fish of 6–8 pounds are the prize winners yearly in Ontario and Quebec, but those taken by anglers usually do not exceed 2–3 pounds in weight. The present angler record is a fish which was 32½ inches (827 mm) long, 28½ inches (724 mm) in girth, 22 pounds 4 ounces in weight, and was caught in Montgomery Lake, Ga., in 1932.

In Canada sexual maturity is reached in 3–4 years by males and 4–5 years by females. Growth rate and ultimate size are greater in females.

Growth increases steadily southward over the range of this species with increased

		Age														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
L. Opinicon	TL *inches*	–	–	9.4	11.1	12.1	13.0	14.3	15.8	16.6	17.1	17.8	18.8	19.7	–	–
(Lewis 1965)	*mm*	–	–	239	282	307	330	363	401	421	434	452	478	500	–	–
	Wt (*lb*)	–	–	0.4	0.7	0.9	1.2	1.6	2.3	2.6	3.1	3.5	4.0	4.9	–	–
L. Simcoe (MacCrimmon	TL *inches*	4.0	8.0	10.0	12.0	13.5	14.5	16.0	17.0	17.5	18.0	19.0	19.8	20.4	21.0	21.4
and Skobe 1970)	*mm*	102	203	254	305	343	368	419	432	445	457	483	503	518	533	544
(pers. comm.)	Wt (*lb*)	–	0.4	0.8	1.7	2.1	–	–	–	–	3.5	–	–	–	5.0	–
Ontario avg	TL *inches*	6.7	8.7	11.3	12.6	13.7	15.4	16.8	17.7	18.0	19.3	18.2	19.8	21.0	–	–
(MacKay 1963)	*mm*	170	196	287	320	348	391	427	450	457	490	462	503	533	–	–
	Wt (*lb*)	0.1	0.5	1.0	1.1	1.5	2.5	3.[illegible]	3.2	3.9	4.0	–	6.3	–	–	–

temperature and almost year-round growth. Viosca (1943) indicated that in Louisiana, fingerlings 7–9 inches (178–229 mm) in length and 5.3–12.0 ounces in weight were produced in 6½ months. He gave other extreme increments for growth in fertilized ponds stocked with forage fishes. The giants of this species are always found in Florida and Georgia.

The habitat of the largemouth is the upper levels of the warm water of small, shallow lakes, shallow bays of larger lakes, and, more rarely, larger, slow rivers. This species is rarely caught at depths over 20 feet. It is almost universally found in association with soft bottoms, stumps, and extensive growths of a variety of emergent and subemergent vegetation, particularly water lilies, cattails, and various species of pond weed. It is rarely found in rocky situations characteristic of the smallmouth bass. The habitat of the largemouth bass usually contains a variety of other sunfishes, the muskellunge or northern pike, yellow perch, brown bullhead, and a variety of minnows. The habitats of the smallmouth and largemouth basses seldom overlap even though the two species often occur in the same lake.

Movement is not extensive, usually less than 5 miles, summer territories are small, and there is some indication of homing to spawning area and summer territory.

The largemouth bass can tolerate higher water temperatures than the smallmouth bass. Temperature preferendum in the field is usually in the range of 79.8°–81.9° F (26.6°–27.7° C) but that determined experimentally ranged from 86.0° to 89.6° F (30° to 32° C) and depends on acclimation temperature (Hart 1952; Ferguson 1958). At higher temperatures in August, largemouth bass become inactive and rest in the shade of aquatic or shore vegetation. Upper lethal temperature shows interesting geographic variation (Hart 1952) and was determined by Black (1953) at 84° F (28.9° C) for bass from British Columbia acclimated at 68.0°–69.8° F (20°–21° C), and by others as high as 97.5° F (36.4° C) for fish acclimated at 86° F (30° C). This bass apparently has a low tolerance of low oxygen conditions and in experiments avoided levels of 1.5 mg/litre and lower. This and their weedy habitat often subjects them to winterkill, and at times summerkill (depletion of oxygen by utilization and decay of plants). Largemouth bass move to the bottom in winter, are more active than smallmouth bass, and are taken by ice fishermen in several northern U.S. states.

Adult largemouth bass are largely fish-eating predators but food type changes with size from plankton, to insects, to fish, crayfish, and frogs. Food is taken at the surface (morning and evening), in the water mass (during day), and from the bottom. This bass is a sight feeder and often feeds in schools near shore and usually close to vegetation. Feeding is restricted at water temperatures below 50° F (10° C) and decreases in winter and during spawning. It has been calculated that it requires 4 pounds of food to produce 1 pound of fish (3.5:1 in the case of smallmouth bass).

There are many detailed analyses of food by size and season in the United States (Turner and Kraatz 1921; Ewers 1933; Cooper 1937; Kramer and Smith 1960b). The food of this species at various lengths, in Lake Opinicon, Ont., was given (Keast and Webb 1966) as follows: 1.2–2.0 inches (30–50 mm) total length — Cladocera (to 50% of the stomach volume), mayfly nymphs (60%), amphipods (25%), chironomid larvae (20%), small quantities of copepods, bugs, and caddisfly nymphs; 2.0–3.8 inches (50–70 mm) — mayfly nymphs (to 40%), dragonfly and damselfly nymphs (20%), crayfish (20%), small quantities of amphipods, chironomid larvae and small fishes; over 3 inches (80 mm) — small fishes (50–90%) and crayfish (10–40%). Frogs, worms, molluscs, and large insect nymphs make up a varying percentage of the food of adults.

Fishes enter in the diet from about 2 inches (50 mm) in length. Fishes mentioned as food of the largemouth bass are gizzard shad, carp, bluntnose minnow, silvery minnow, golden shiner, carp, yellow perch, pumpkinseed, bluegill, largemouth bass, and silversides. Doubtless almost any species of fish of appropriate size is eaten. Cannibalism is higher in this species than in the smallmouth bass. It has been reported that up to 10% of the food of largemouth bass 8 inches (203 mm) and over is the fry of the same species. Largemouth bass 1.5–1.8 inches (40–47 mm) in length are known to have eaten bass as large as 0.9–1.2 inches (24–30 mm) in length.

The young and small adults are doubtless part of the food of other predaceous fishes which share the habitat, such as yellow perch, walleye, northern pike, and muskellunge, as well as such birds as heron, bittern, and kingfisher. Adult largemouth, as a result of size, spines and swimming speed, seem largely to escape predation. Crayfish, dragonfly larvae, predaceous diving beetle larvae, other sunfishes, and golden shiners are significant egg and fry predators. Young largemouth bass compete for food with a wide variety of other bottom-feeding warmwater fishes. Adults compete for food with all other shallow-water predaceous fishes in their habitat, and with other sunfishes for spawning sites. However, water temperature at spawning time, wave action, nest desertion, parasite sterility, and availability of food for newly rising fry are said to be more operative in controlling recruitment than is predation or competition.

The parasites listed by Hoffman (1967) for this species over the whole of its range were: Protozoa (13), Trematoda (45), Cestoda (11), Nematoda (14), Acanthocephala (5), leeches (4), Mollusca (1), Crustacea (10). There is extensive literature on the parasites of the black basses and certainly one of the earliest papers on parasites of Canadian fishes was that of Wright (1884) on a parasitic copepod of this species. Bangham (1955), Bangham and Hunter (1939), and Bangham and Adams (1954), listed them for Canadian habitats. One of the early studies of the bass tapeworm was carried out in Canada by Cooper (1915).

As with the smallmouth bass, the parasites of most concern to man are the bass tapeworm, black-spot, and yellow grub. The tapeworm, by causing sterility reduces yield, the other two are unsightly. None of them is dangerous to man, especially in cooked fish.

Hester (1970) gave details of a number of artificial hybrids of this species but apparently none are known in nature.

Relation to man Like the smallmouth bass, this species is one of the major sport fishes in eastern Canada. The area in which it is important in Ontario is smaller (mainly Rideau and Kawartha Lake systems), but there and in southern Quebec the fishery for it is as intense and as important to the local economy as that for smallmouth bass elsewhere. Like the smallmouth bass, this species was taken commercially by the ton until about 1936. The catch statistics generally listed only black basses or basses, the two were not separated. The largemouth formed a smaller but significant part of this catch in Ontario and Quebec. After that time they were generally restricted as a sport fish. This species is caught still fishing with worms, minnows, or frogs or by casting, particularly in the evening, in weedy, stumpy areas with large, often noisy, surface plugs or with bass "bugs" or poppers. Largemouth bass take surface lures more frequently and flies less frequently than do smallmouth bass. The flesh is excellent and the fish easily filleted to obtain large pieces of skinless, flaky meat. There are many detailed accounts of the sport fishery for this species in the United States (*see* Mraz and Threinen 1957; and Maloney et al. 1962) but few in Canada. A study of the fishery in Lake Opinicon, Ont., (Lewis 1965) gave extensive information on availability, catch, size etc. It indicated that the best catches were obtained by guided parties and in July, success varied from year to year and decreased over the summer but that average rates of 0.5–0.3 fish per hour indicated good fishing.

The largemouth bass, with its tolerance for high temperature and slight turbidity, its fast growth rate, and fish diet have made it a favourite for stocking warmwater farm ponds for food and sport. Such ponds have received considerable attention in the United States (*see* various papers by Swingle and *also* Regier 1963a) and now in Canada (*see* Johnson and McCrimmon 1967). They are usually stocked with bass and a forage fish such as bluegills or golden shiners.

Nomenclature

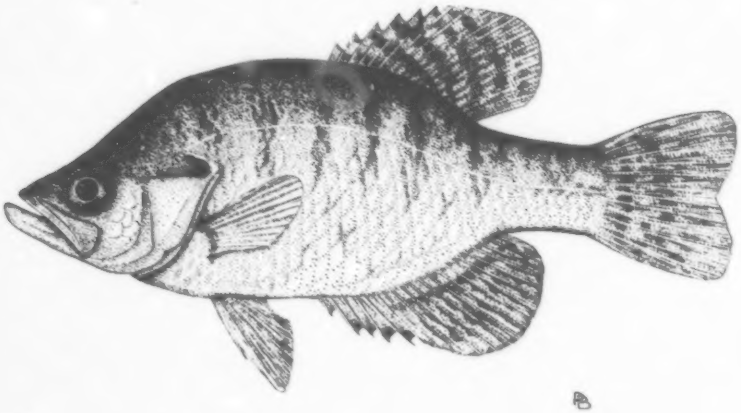
Labrus salmoides — La Cepède 1802: 716 (type locality South Carolina)
Huro nigricans — Cuvier and Valenciennes 1828: 108
Perca (Huro) nigricans (Cuvier) — Richardson 1836: 4
Grystes nigrisans — Forelle 1857: 278
Grystes megastoma — Garlick 1857: 108
Micropterus salmoides (Lacépède) — Jordan and Evermann 1896–1900: 1012
Aplites salmoides Rafinesque — Hubbs 1926: 71
Aplites salmoides Lacépède — Hubbs and Greene 1928: 391
Aplites salmoides (Lacépède) — Dymond et al. 1929: 30
Huro salmoides (Lacépède) — Hubbs and Lagler 1941: 78
Micropterus salmoides (Lacépède) — Hubbs and Lagler 1947: 93

Etymology *Micropterus* — small or short fin, a damaged second dorsal led Lacépède to think there was a short fin at the rear of it; *salmoides* — trout-like, the original came from southern United States, where it was, and still is, referred to as green trout.

Common names Largemouth bass, northern largemouth bass, large mouth or large-mouth bass, large mouthed or large-mouthed bass, largemouth, black bass, largemouth black bass, green bass, bass. French common name: *achigan à grande bouche*.

WHITE CRAPPIE

Pomoxis annularis Rafinesque



Description A moderately large, deep-bodied sunfish, more elongate than the black crappie, with extreme lateral compression. Individuals in Canada are usually not over 8–10 inches (203–254 mm) in length. Greatest depth far back but at origin of dorsal fin, 23.8–29.0% of total length, less than in black crappie, angle from snout to dorsal fin only moderately steep, less so than in black crappie, back somewhat flattened; caudal peduncle rather long, somewhat narrower than black crappie. Head long, 25.3–27.9% of total length, rather deep but shallower than black crappie, very narrow, marked depression over eye, operculum bony to edge and rather pointed, flap not extended, but small, vague, black spot in from edge of operculum; eye large, 24.5–29.4% of head length, well ahead of centre of head and high; snout short, not so deep as black crappie, rather sharply pointed; mouth terminal, somewhat oblique, large, rather large lower jaw longer than upper, gape reaching to posterior nostril; maxillary very long, 36.8–41.5% of head length, reaching to posterior margin of eye; fine teeth on both jaws and palatines; lower pharyngeal pads very long and narrow with fine, brushlike teeth. Gill rakers very numerous, long, and thin, usually 22–24 on lower limb and 6–8 on upper limb. Branchiostegal rays 7. Fins: dorsals 2, but so joined and rays so graduated in length as to appear as 1, base of dorsals less than base of anal fin, also shorter than and farther back than in black crappie, base length equals distance from dorsal origin to opercular root, and distance from tip of snout to dorsal origin is 36.5–40.2% of total length, base of first dorsal shorter than that of second dorsal, first dorsal with 6 (rarely 7) spines of graduated length, last spine almost as high as second dorsal, second dorsal fin longer, higher, soft rayed, with 13–15 (but usually 14 or 15) rays, edge rounded; caudal moderately long, shallowly forked, tips rounded; anal with long base, longer than dorsals, 6 or 7 graduated spines followed by 16–18 soft rays (usually 6 spines and 17 rays), edge squarish to rounded; pelvics thoracic, origin under pectoral fins far in advance of origin of dorsal fin, base with broad attachment to body, moderately long, tip overlaps origin of anal fin, edge square to rounded, tip a blunt point, 1 spine and 5 rays; pectorals high, not long nor overly broad, and rounded, usually 13 rays. Scales mostly ctenoid, rather large, markedly smaller and crowded on anterior dorsal surface; lateral line complete, high, shallowly arched over pectoral fin, 34–44 lateral line scales. Peritoneum silvery, intestine well differentiated, usually 10 thin, but well-marked caeca. Vertebrae 30–32.

No nuptial tubercles but dark pigment and iridescent colours intensify on males at breeding time.

Hofstetter et al. (1958) gave skeletal characteristics by which white and black crappies can be distinguished.

Colour Dorsal surface of body and head dark green, olive, to brownish, with blue-green or silver overcast; upper sides lighter, more iridescent green, shading to silver; with 5–10 vague, vertical bands of black sometimes extending down to anal fin but more obvious on lower back and upper sides; ventral surface silvery to milk white; sometimes iridescent pink or green on opercular bones; eye yellow to green; amount of black pigment variable with location and size; dorsal, caudal, and anal fins with black vermiculations or rows of distinct black spots, pelvic fins opaque white, pectoral fins transparent amber to yellow, no black on paired fins.

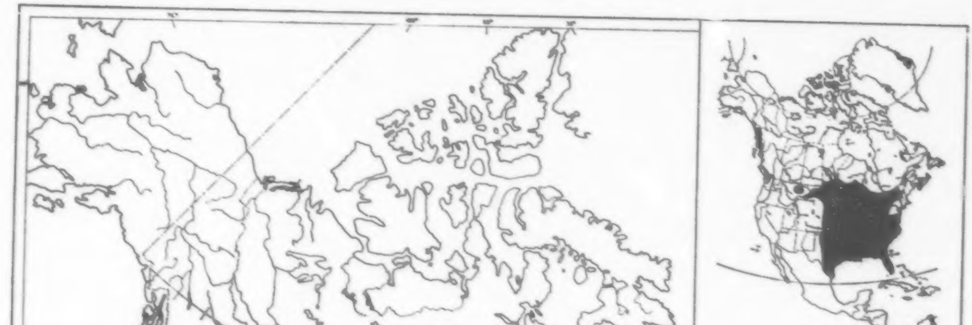
The young have much less black pigment and the black on head, chin, and breast intensifies on breeding males.

Distribution The natural range of this sunfish is restricted to the fresh waters of east-central North America. It now occurs from southwestern New York, south, west of the Appalachian Mountains to the Gulf coast area of Alabama, north in the Atlantic coast states to North Carolina, from Alabama west to eastern Texas, north through the eastern halves of the states to South Dakota and southern Minnesota, east across lower Michigan into southern Ontario. It is apparently widely introduced outside of this area in the United States, including Washington, Oregon, California, and Connecticut.

In Canada this species occurs only in Ontario in the area of western Lake Ontario, all of Lake Erie, Lake St. Clair, and Lake Huron as far north as Manitoulin Island. The latter is the most northerly record in Canada and, possibly, of its entire range. In the Great Lakes area and in Ontario, in general, this crappie is much less abundant, and less frequently seen than the black crappie, for which it is no doubt often mistaken.

Biology There is virtually no information available on the biology of this species in Canada. Excellent summaries of United States populations were written by Hansen (1951, 1965) and Siefert (1968) from which the following was derived.

Spawning takes place for approximately a 29-day period in late spring to early summer when water temperatures are 57.2°–73.4° F (14°–23° C) and is most active at 60.8°–68.0° F (16°–20° C). The aggressive, territorial males come on to the spawning grounds first and clean ill-defined nests of a diameter of 11.8 inches (300 mm), with no depression, over a variety of bottom types, in about 8–38 inches (200–970 mm) of water. Rooted plants or algae are usually beside or in the nest. At times, nests are established in the protection of undercut banks. Nests are isolated or sometimes in colonies of 35–50, 2–4 feet (50–122 cm) apart. Spawning takes place in the mornings with little of the active, circular swimming characteristics of other sunfishes. Spawning acts are short, with the same pair taking part in as many as 50, with 0.5–20 minutes separating them. Only a small part of the eggs is released at any time and the same females may spawn in the nests of several different males. Egg number per female is probably similar to the 27,000–68,000 noted for black crappies of the same size. One female in Ohio, 4.3 inches (109 mm) long, contained 14,750 eggs. Eggs are 0.89 mm in diameter, colourless, demersal, and adhesive. They adhere to the substrate, especially to algae, and to one another. The male guards the nest and fans the eggs. At a water temperature of 57.9° F (14.4° C) eggs hatch in about 4 days, with a range of 2–4½ days depending on temperature. The tiny, transparent, young remain on the nest for only a short period and in some cases only 4 days elapse from start of hatching to depar-



ture of the young. Siefert (1969) gave characteristics for separating the very similar young of the white and black crappies.

Growth is rapid at first and Trautman (1957) said that young-of-the-year, in October, in Ohio were 1.0–3.8 inches (25–97 mm) long. Later growth is quite variable depending on habitat. The following age–length relation given by Roach and Evans (1948) for Ohio, will probably be slightly higher than that for Ontario.

Age	Length (*inches*)	(*mm*)
0+	–	–
1+	2.6	66
2+	5.4	137
3+	7.6	193
4+	9.0	229
5+	10.4	264
6+	11.8	300
7+	13.7	348
8+	15.7	399

Sexual maturity is attained in the second to fourth year and fish on nests are usually 6–8 inches (152–203 mm) in length. Stunting occurs. In Ontario, white crappies may reach 10–12 inches (254–305 mm) and a pound in weight, but are usually 7–10 inches (178–254 mm) long. Adults in Ohio are usually 5–14 inches (127–356 mm). Trautman (1957) quoted maximum size as 17.2 inches (437 mm) and a weight of just over 3 pounds. The present angler record is either one which weighed 5 pounds 3 ounces, was 21 inches (533 mm) long, and was caught at Enid Dam, Miss., in 1957, or one of 6 pounds from Louisiana. Maximum age would appear to be 8–10 years.

In Ontario this fish is usually found in rather silted streams, lakes, ponds, and muddy, slow-moving areas of larger rivers. In the Great Lakes it is most often captured in the mouths of tributary streams, or in warm, weedy, sheltered bays.

The food of the young is a variety of

plankton crustaceans but adult white crappies eat aquatic insects, some crustaceans, and a large number of small fishes. Hansen (1951) gave the following percentage volumes for white crappies in Illinois: fishes (57.8%), aquatic insects (34.9%), unidentified animal matter (5.06%), other aquatic invertebrates (1.17%).

Young white crappies probably fall prey to the same variety of predaceous fishes as do other sunfishes including largemouth bass, and larger white and black crappies. The larger individuals with their deep bodies may be fairly free of predation. Their numbers in Canadian waters preclude the possibility of them being of any significance as predators or competitors.

The parasites of this species, over the whole of its range, listed by Hoffman (1967) were: Protozoa (5), Trematoda (9), Cestoda (2), Nematoda (5), Acanthocephala (2), leeches (4), Crustacea (5).

Bangham and Hunter (1939) listed, for this species, from Lake Erie, nematodes *Spinitectus gracilis*, *Camallanus oxycephalus*, and *Agamonema* sp., the acanthocephalan *Leptorhynchoides thecatus*, the copepod *Ergasilus centrarchidarum*, and an encysted myxosporidian.

Bangham (1955) listed only *Camallanus oxycephalus* and *Proteocephalus pearsei* for South Bay, Lake Huron.

The white crappie is known to hybridize in nature only with the black crappie.

Relation to man This crappie is too uncommon to be of any real significance as a commercial or sport fish in Canada. It probably contributes, to a minor extent, to those fish marketed in Ontario and recorded in the statistics as rock bass and crappies. Anglers recognize crappies but rarely distinguish between this rarer form and the more common black crappie. A small number of this species is probably taken by anglers still fishing with worms or minnows in rather shallow water. The flesh is white, flaky, and highly suitable as food but their heavy, compressed, bony bodies make preparation difficult for some people. It is an important sport fish over much of its range in the United States. Anglers use small minnows for still fishing or small silvery spoons, spinners, or jigs to cast or troll.

Nomenclature

Pomoxis annularis — Rafinesque 1818d: 41 (type locality Ohio River)

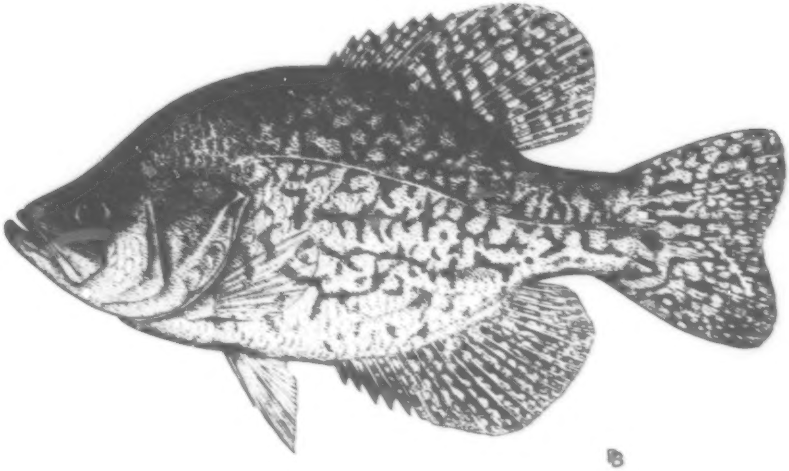
It would appear that the scientific name of few species of North American freshwater fishes have enjoyed the stability that this one has. There are few synonyms and all Canadian records found to date have used this name.

Etymology *Pomoxis* — sharp opercle, alluding to the fact that the opercle ends in a point rather than a flap; *annularis* — having rings, the vague vertical bars of the body.

Common names White crappie, crappie, crawpie, silver bass, white bass. French common name: *marigane blanche*.

BLACK CRAPPIE

Pomoxis nigromaculatus (Lesueur)



Description A large, deep-bodied sunfish, less elongate than the white crappie, with extreme lateral compression. Individuals in Canada are usually 7–10 inches (178–254 mm) in length. Greatest depth far back, at origin of dorsal fin, 29.7–33.3% of total length, greater than in white crappie, angle from snout to dorsal fin steeper than white crappie, back rounded; caudal peduncle appears shorter and deeper. Head long, 26.6–28.3% of total length, deeper than white crappie, very narrow, marked depression over eye, operculum bony to edge and rather pointed, no extended flap, rather large, diffuse, black spot at edge of operculum; eye usually larger than white crappie, diameter 25.0–31.6% of head length, eye ahead of centre of head and high; snout short, somewhat deeper than white crappie, slightly pointed; mouth terminal, oblique, large, large lower jaw slightly longer than upper, gape reaching to posterior nostril; maxillary long, 40.9–45.8% of head length, reaching to posterior edge of pupil; fine teeth on both jaws and palatines; lower pharyngeal pads very long, very narrow, with fine, brushlike teeth. Gill rakers very numerous, long and slender, usually 22 or 23 on lower limb and 5 or 6 on upper limb. Branchiostegal rays 7. Fins: dorsals 2, but so joined and rays so graduated in length as to appear as 1, length of base of dorsal fins very little less than base of anal fin, dorsals with longer base and not so far back compared to white crappie, base length equals distance from dorsal origin to middle of eye, and distance from tip of snout to dorsal origin is 32.3–39.1% of total length, first dorsal with base shorter than that of second, with 7 or 8 spines of graduated length, last almost as high as second dorsal fin, second dorsal fin longer, higher, soft rayed with 14–16 rays (most often 8 spines and 14 rays), edge rounded; caudal long, broad, shallowly forked, tips rounded; anal with long base but little longer than that of dorsals, 6 or 7 graduated spines followed by 16–18 soft rays (usually 6 spines and 17 rays), edge rounded to squarish; pelvics thoracic, origin under pectoral fins, less advanced from origin of dorsal fin than in white crappie, base with broad attachment to body, moderately long, tip overlaps anal fin origin, edge square, tip a rounded point, 1 fine spine and 5 rays; pectorals moderately high on body, moderately long, broad, and rounded, usually 13–15 rays. Scales mostly ctenoid, rather large, but smaller and crowded on anterior dorsal surface and breast; lateral line complete, high, shallowly arched over pectoral fin, 36–41 lateral line scales. Peritoneum silvery, intestine well differentiated, usually 8 caeca. Vertebrae 31–33.

No nuptial tubercles but dark pigment and iridescent colours intensify on males at breeding time.

Hofstetter et al. (1958) gave skeletal characteristics by which the black and white crappies can be distinguished.

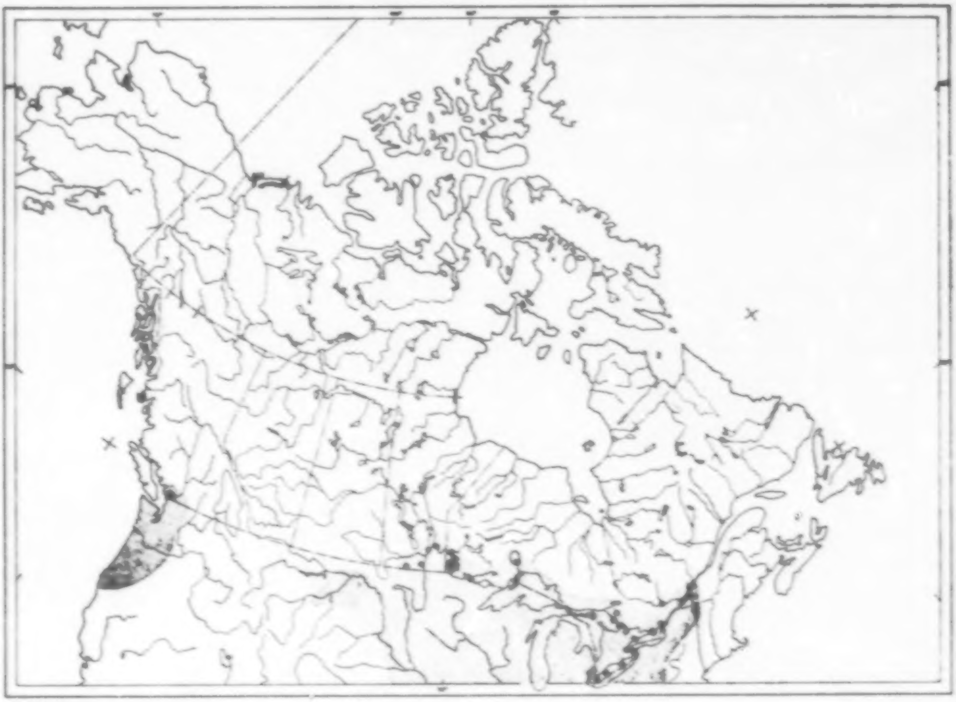
Colour Dorsal surface of back and head olive, metallic green to golden brown with overcast of silver or blue; sides lighter, iridescent green to silvery; head and sides with an irregular mosaic of black blotches, no vertical rows but vague horizontal grouping of body pigment; intensity of pigment varies with habitat and size; dorsal, caudal, and anal fins strikingly vermiculated with black, forming round or oblong yellow to pale green spots in centres of vermiculations, pelvic fins opaque with some black on tips of membranes, pectoral fins dusky and transparent. Individuals from clear, vegetated water with darker, contrasting pattern, fish from turbid waters bleached looking. Young with less dark pigment and pattern.

In breeding males the black, particularly on the head, becomes darker and velvety in colour. Most of the eye is marked in this way.

Distribution The natural range of this species is restricted to the fresh waters (and rarely brackish water) of eastern and central North America. It occurs from Quebec south through western New York, west of the mountains to the Gulf coast in Alabama, east through all of Florida and north along the Atlantic coast to Virginia, west from Alabama to central Texas, north through the eastern half of the states from Oklahoma to South Dakota, most of North Dakota and in eastern Montana, east through southern Manitoba, Ontario, and Quebec. It has been so widely introduced almost everywhere in the United States, west and east, that it is now virtually impossible to define the western limit of natural distribution.

In Canada this species occurs in Quebec in the St. Lawrence and its tributaries, downstream to at least brackish waters at a point near Rivière Ouelle (Vladykov 1949c), the Richelieu–Champlain system, and the Ottawa River, generally throughout Ontario north to a line from Temiskaming to Sault Ste. Marie, the Great Lakes, now including Lake Superior (as a result of spread from introduction in a nearby lake), west through Lake of the Woods to central southern Manitoba in the Red and Assiniboine rivers (rare). This sunfish is also present in backwaters and tributaries of the lower Fraser River in British Columbia. Black crappies are probably most abundant in eastern Ontario, in the Rideau Lakes, the upper St. Lawrence River, and in certain areas of Georgian Bay.

Biology Other than on food and feeding, very little is known of the biology of this sunfish in Canada. Much of the following was derived from Pearse (1919), Breder (1936b), and Breder and Rosen (1966). The black crappie spawns in late spring and early summer starting when water temperature is 66°–68° F (19°–20° C). This is usually in late May to mid-July. Occupation of spawning territory and nest building by males can begin slightly earlier. Males clear shallow depressions or just clear a section of the bottom of sand, gravel, or mud, in water 10 inches to 2 feet (254–610 mm) deep, where there is some vegetation. At times nests are cleared in the protection of an undercut bank. Males guard the nest, guard and fan the eggs till they hatch, and guard the young for a short time. Nests are 8–15 inches (203–381 mm) in diameter, colonial but 5–6 feet (152–183 cm) apart. The spawning activity of the male and female of this species is similar to that of the white crappie. Females probably spawn with different males in more than



one nest. Eggs are slightly less than 1 mm in diameter, whitish, demersal, and adhesive. Egg number for females 7.6–9.0 inches (195–230 mm), 3 and 4 years of age, are 26,700–65,520, with the average number of 37,796 per female (Ulrey et al. 1938). Eggs hatch in 3–5 days, the minute, transparent young are guarded by the male for a few days and then they desert the nest. Siefert (1969) gave characteristics for separating the very similar young of the white and black crappies. The young of the black crappie are more elongate at first, like those of largemouth bass.

Growth is rapid at first and young-of-the-year in Ohio are 1–3 inches (25–76 mm) in October (Trautman 1957). The following table shows the age–length relation for black crappies from Lake of the Woods, in Ontario, and for lakes in Michigan given by Beckman (1949).

Growth varies tremendously with size of population and with size and productivity of the habitat.

	Lake of the Woods, Ont.			Michigan lakes	
Age	FL		Wt	TL	
	(inches)	*(mm)*	*lb*	*(inches)*	*(mm)*
0	–	–	–	–	–
1	4.4	112	0.1	–	–
2	6.6	168	0.2	5.9	150
3	8.4	213	0.4	8.0	203
4	10.0	254	0.7	9.0	229
5	10.5	267	0.7	9.9	251
6	11.1	282	0.9	10.7	272
7	11.4	290	1.0	11.3	287
8	12.0	305	1.1	11.6	295
9	12.5	318	1.3	–	–

Maximum size in Ontario is usually 12–14 inches (305–356 mm) and some may reach a weight in excess of 2 pounds. Individuals over 1 pound weight are regularly caught in Lake of the Woods and Georgian Bay. Trautman (1957) listed 15.1 inches (384 mm) and 2 pounds 4 ounces as maximum size. The present angling record is one of 5 pounds, 19¼ inches (489 mm) in length, 18½ inches (470 mm) in girth, and was caught in the

Santee–Cooper Reservoir, S.C., in 1957. Sexual maturity is attained in the second to fourth year. Maximum age would appear to be 8–10 years.

The black crappie is usually found in the clear, quiet, warm water of large ponds, small lakes, bays and shallower areas of larger lakes, and areas of low flow of larger rivers. They are almost always associated with abundant growths of aquatic vegetation, sandy to mucky bottoms, and are less often found in turbid situations than the white crappie. This species is usually found in discrete, moderately large schools.

The food of this sunfish is widely treated in the literature and that of Canadian populations is discussed in detail by Keast and Webb (1966), Keast and Welsh (1968), and Keast (1968a, b). Feeding is most active in the open water mass, in the early morning and between midnight and 2 AM. Diet changes with size and age. In Lake Opinicon the smaller, younger crappies feed on planktonic crustacea and free-swimming, nocturnal, dipterous larvae *(Chaoborus* and *Procladius).* This invertebrate diet continues into the third year of life and for individuals as large as 6.3 inches (160 mm). The ability to effectively utilize small invertebrates as a result of the numerous, fine, long gill rakers probably accounts for this diet in such large individuals of what is usually considered a piscivorous species. Beyond that size a variety of very small fishes makes up an increasing proportion of the diet. In Lake Opinicon the following were eaten: yellow perch, bluegill, pumpkinseed, black crappie (rare), blackchin shiner, golden shiner, bluntnose minnow, largemouth bass, and smallmouth bass. Perch, which share their open water habitat, were most often eaten and the prey usually ranged from 1.3–2.4 inches (35–60 mm) in length and were never over 2.5 inches (65 mm). The main foods in Lake Opinicon lumping all sizes of crappies were: *Chaoborus* larvae (up to 70% of stomach volumes), cladocerans (to 50%), copepods (20%), fishes (25%), flying insects (15%), chironomid pupae and larvae (25%), ephemeropteran nymphs (10%). The literature and ice fishery suggest that crappies are active and feed all winter but stomachs of fish taken from under the ice suggest they feed little before mid-April.

The young of the black crappie are probably the prey of a variety of warmwater predaceous fishes such as largemouth bass, smallmouth bass, larger sunfishes including black crappies, northern pike, and muskellunge. The spines and gibbous body of the larger adults probably make predation negligible. Their long planktivorous period and their open water feeding reduce the degree to which they compete for food with other valued species.

The parasites listed by Hoffman (1967) for the black crappie over the whole of its range were: protozoans (14), trematodes (19), cestodes (5), nematodes (9), acanthocephalans (4), leeches (1), crustaceans (5). For Canadian habitats the parasites were listed for Lake Erie (Bangham and Hunter 1939), for British Columbia (Bangham and Adams 1954), and for Lake Huron (Bangham 1955).

The black crappie is known to hybridize in nature only with the white crappie.

Relation to man This is another of the abundant species which is both a commercial fish and a sport fish and for which there are no size, catch, or season regulations. They are taken by commercial fishermen in gillnets and trapnets. This sunfish often has attracted a price (as round fish) equal to or in excess of the highly valued walleye. In 1965 price paid was 33¢/pound and one fisherman in Lake of the Woods landed $2500 worth in one day. The Ontario statistics lump both crappies with rock bass. It is probable, however, that the black crappie made up a considerable share of the 271,411 pounds of fish so listed and worth $60,417.45 in 1966. The productive areas, in descending contribution, were: northern inland lakes (Lake of the Woods?), lakes St. Clair, Erie, and Ontario, southern inland lakes, North Channel of Lake Huron, and Lake Huron.

The black crappie is an important sport fish over the whole of its range. This shallow-water, schooling, highly edible fish can often be caught in the period just before sunset as fast as the hook can be rebaited. Since many are over 1 pound weight, they provide considerable fun and food to anglers in eastern Ontario, Georgian Bay, and Lake of the Woods. The flesh is white, flaky, and very tasty. There is also a significant and successful winter fishery for them in certain specific areas of Lake of the Woods (Chambers 1966).

Nomenclature

cantharus nigro-maculatus — LeSueur 1829 *in* Cuvier and Valenciennes 1828–1849: 88 (type locality Wabash River, Ohio)
Pomoxys sparoides — Wright 1892: 455
Pomoxis sparoides (Lacépède) — Jordan and Evermann 1896–1900: 997
Pomoxis nigro-maculatus (LeSueur) — Bailey 1941: 22
Pomoxis nigromaculatus (LeSueur) — Bailey 1951: 194

Etymology *Pomoxis* — sharp opercle; as opposed to extended in a flap as in some other sunfishes; *nigromaculatus* — black spotted.

Common names Black crappie, crappie, crawpie, calico bass, strawberry bass, speckled bass, grass bass, Oswego bass, shiner, moonfish. French common name: *marigane noire.*

Suggested Reading — Centrarchidae

Bailey, R. M. MS 1938. A systematic revision of the centrarchid fishes, with a discussion of their distribution, variations, and probable interrelationships. Ph.D. Thesis. Univ. Michigan, Ann Arbor, Mich. 256 p.

Branson, B. A., and G. A. Moore. 1962. The lateralis components of the acoustico–lateralis system in the sunfish family Centrarchidae. Copeia 1962: 1–108.

Breder, C. M., Jr. 1936. I. The reproductive habits of the North American sunfishes (family Centrarchidae). Zoologica 21: 1–48 + 1 pl.

Carbine, W. F. 1939. Observations on the spawning habits of centrarchid fishes in Deep Lake, Oakland County, Michigan. Trans. 4th N.A. Wildl. Conf. p. 275–287.

Cuerrier, J.-P. 1945. L'achigan. Carnets 5(2): 32–37.

Dymond, J. R. 1931. The small-mouthed black bass and its conservation. Ont. Dep. Game Fish., Biol. Fish Cult. Br. Bull. 2: 10 p.

Gerking, S. D. 1966. Annual growth cycle, growth potential, and growth compensation in the bluegill sunfish in northern Indiana lakes. J. Fish. Res. Bd. Canada 23: 1923–1956.

Hansen, D. F. 1951. Biology of the white crappie in Illinois. Bull. Ill. Natur. Hist. Surv. 25: 211–265.

Henshall, J. A. 1917. Book of the black bass. Stewart and Kidd Co., Cincinnati, Ohio. 452 p.

Hester, F. E. 1970. Phylogenetic relationships of sunfishes as demonstrated by hybridization. Trans. Amer. Fish. Soc. 99: 100–104.

Hile, R. 1941. Age and growth of the rock bass, *Ambloplites rupestris* (Rafinesque), in Nebish Lake, Wisconsin. Trans. Wis. Acad. Sci. Arts Lett. 33: 189–337.

HUBBS, C. L., and R. M. BAILEY. 1938. The small-mouthed bass. Cranbrook Inst. Sci. Bull. 10: 92 p.

1940. A revision of the black basses (*Micropterus* and *Huro*) with descriptions of four new forms. Misc. Publ. Mus. Zool. Univ. Mich. 48: 1–51.

HUBBS, C. L., and L. C. HUBBS. 1933. The increased growth, predominent maleness, and apparent infertility of hybrid sunfishes. Pap. Mich. Acad. Sci. Arts Lett. 17: 613–641.

HUISH, M. T. 1954. Life history of the black crappie of Lake George, Florida. Trans. Amer. Fish. Soc. 83: 176–193.

JONES, S. R. 1924. Black bass and black bass craft; the life habits of the two bass and successful angling strategy. Macmillan Co., New York, N.Y. 205 p.

LATTA, W. C. 1963. The life history of the smallmouth bass, *Micropterus d. dolomieui*, at Waugoshance Point, Lake Michigan. Mich. Dep. Conserv. Bull. Inst. Fish. Res. 5: 1–56.

LOUDON, W. J. 1910. The small-mouthed bass. Hunter-Rose Co. Ltd., Toronto, Ont. 103 p.

MRAZ, D., S. KMIOTEK, and L. FRANKENBERGER. 1961. The largemouth bass. Its life history, ecology and management. Wis. Conserv. Dep. Publ. 232: 13 p.

REIGHARD, J. 1906. The breeding habits, development and propagation of the black bass (*Micropterus dolomieu* Lacépède and *Micropterus salmoides* Lacépède). Bull. Mich. Fish Comm. 7: 73 p. + 29 fig.

ROBERTS, F. L. 1964. A chromosome study of twenty species of Centrarchidae. J. Morphol. 115: 401–418.

SCOTT, D. C. 1949. A study of a stream population of rock bass. Invest. Indiana Lakes Streams 3(3): 169–234.

SEABURG, K. G., and J. B. MOYLE. 1964. Feeding habits, digestive rates and growth of some Minnesota warmwater fishes. Trans. Amer. Fish. Soc. 93: 269–285.

SMITHERMAN, R. O., and F. E. HESTER. 1962. Artificial propagation of sunfishes, with meristic comparisons of three species of *Lepomis* and five of their hybrids. Trans. Amer. Fish. Soc. 91: 333–341.

SNOW, H., A. ENSIGN, and J. KLINGBIEL. 1960. The bluegill. Its life history, ecology and management. Wis. Conserv. Dep. Publ. 230: 14 p.

SWINGLE, H. S. 1946. Experiments with combinations of largemouth black bass, bluegills, and minnows in ponds. Trans. Amer. Fish. Soc. 76: 46–62.

WEBSTER, D. W. 1954. Smallmouth bass, *Micropterus dolomieu*, in Cayuga Lake. (Part 1. Life history and environment.) Agr. Exp. Sta. Cornell Univ. Mem. 327: 39 p.

WESTMAN, J. R., and C. B. WESTMAN. 1949. Population phenomena in certain game fishes of Lake Simcoe, Ontario, and some effects on angling returns. Part I. The smallmouth bass, *Micropterus dolomieu* Lacépède. Can. J. Res. D(27): 7–29.

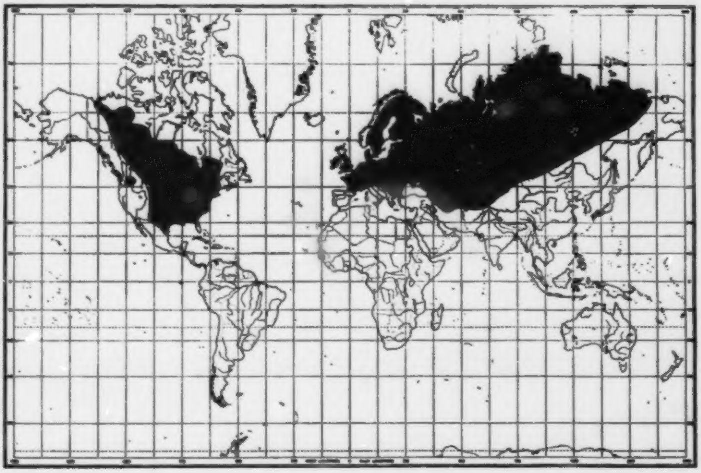
PERCH FAMILY — Percidae

This is the typical family of the order Perciformes. The members of the family are usually elongate, terete, and somewhat laterally compressed. The mouth may be large or small, terminal or inferior, and the premaxillary may or may not be protractile. Teeth present on jaws, vomer, and palatines usually villiform and in bands, but canines present in some forms. The lower pharyngeals bear sharp teeth. The two dorsal fins are well separated in contrast to dorsal fins of the sunfishes, family Centrarchidae. The first dorsal has 6–15 spines. The pectoral fins are moderately long and the pelvic fins are thoracic and have 1 spine and 5 rays. The anal fin is small with 1 or 2 spines, and the caudal fin lunate, truncate, or rounded. The preopercle is entire or serrate, usually ending in a single, flat spine. Swim bladder if present is physoclistous.

The family Percidae consists of 2 subfamilies, 9 genera and 121 species, the subfamily Percinae of 6 genera and about 16 species, and the subfamily Etheostomatinae, the darters, of 3 genera and 107 species. The darters are restricted to North America.

In North America the perches inhabit warm temperate to cold, subarctic streams and lakes. The darters flourish in a variety of environments from warm to cool temperate waters. The family is circumpolar in distribution, but most species are restricted to North America.

Percids have been known from Upper Cretaceous and the Oligocene of Europe, and from the Eocene of North America.



World Distribution of the Perches

KEY TO SPECIES

1 Mouth large, maxillary extending to mid-point of eye or beyond; lower borders of preopercle obviously serrate; branchiostegals 7 or 8 (rarely 6); moderate to large fish. 2

Mouth small, maxillary usually not extending beyond anterior margin of eye; lower borders of preopercle smooth, not serrate; branchiostegals 6 or 7 (rarely 5); small, bottom dweller, never over 6 inches (152 mm) in length. (darters) 4

2 Anal fin with 2 spines and 6–8 soft rays; teeth in lower jaw all about equal height, no canines on tip; space between pelvic fins less than width of base of 1 fin; body deeper and laterally compressed, with 6–8 wide, dark, vertical bars. .... YELLOW PERCH, *Perca flavescens* (p. 755)

Anal fin with 2 spines and 12 or 13 soft rays; canine teeth present, usually 2 on tip of lower jaw; space between pelvic fins equal to or greater than base of 1 fin; body shallower and subcylindrical 3

3 Rays of second dorsal fin usually 18–22, membrane of first dorsal dusky without definite spots, a large black blotch at posterior base of spinous dorsal in adults; lower lobe of caudal fin with white tip; in adults cheek scales small, hard to see, cheek and operculum naked at 6 inches (152 mm) in length; 3 pyloric caeca each about as long as stomach; 5–7 dark saddles on back. .... WALLEYE, *Stizostedion vitreum*[1] (p. 767)

Rays of second dorsal fin usually 17–20; membrane of first dorsal clear with definite spots; in young pigment absent or confined to upper edge, no large blotch at posterior base; lower lobe of caudal fin usually without white tip; in adults cheek scales more apparent, cheek naked but scales on operculum obvious at 6 inches (152 mm) in length; usually 5 (3–9) pyloric caeca, each shorter than stomach; back with 3 or 4 saddles which become patches below fins and on peduncle. .... SAUGER, *Stizostedion canadense* (p. 762)

4 Anal fin large, equal to or larger than soft dorsal fin; pelvic fins well separated; caudal fin usually slightly forked; lateral line usually complete; space between pelvic base and along belly either naked or with enlarged ctenoid scales, females sometimes with only 1 enlarged scale between pelvic fins; body usually elongate and shallow 5

Anal fin smaller than soft dorsal fin; distance between pelvic fins variable, from width of pelvic base to one-half pelvic base; caudal fin slightly forked, square, or rounded; lateral line complete or incomplete; space between pelvic fins and along belly either naked or with scales, but scales never enlarged; body usually somewhat compressed laterally 9

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[1] No attempt is made here to separate the subspecies *Stizostedion vitreum glaucum*, the blue pike. The species occurred only in Lakes Erie and Ontario and apparently has been extirpated. Specimens of a dull grey form reported from various inland lakes have proven to be colour mutants of the walleye, *S. v. vitreum*.

5 Flesh pellucid in life; anal fin with a single thin spine; dorsal fins widely separated; body extremely elongate and partially naked, with scales confined to midline of sides; a series of 10–12 small, rounded, green spots along midline of sides. .... EASTERN SAND DARTER, *Ammocrypta pellucida* (p. 775)

Flesh opaque; anal fin with 2 spines; dorsal fins not widely separated; body usually scaled 6

6 Premaxillaries protractile, clearly separated from snout by a deep groove; a series of small, brown, oblong, or round blotches along sides, frequently joined together by a thin line. .... CHANNEL DARTER, *Percina copelandi* (p. 801)

Premaxillaries not protractile (a shallow groove may be evident in *P. shumardi*) 7

7 Snout prolonged to form a conical protuberance, projecting beyond upper jaw; lateral line scales 78–103; body with 14–16 dark, vertical bars, alternate bars being expanded and drop-like at lower ends; a distinct black spot at caudal base. .... LOGPERCH, *Percina caprodes* (p. 797)

Snout not prolonged, not projecting beyond upper jaw; lateral line scales fewer than 78; body with lateral blotches, with or without black spot at caudal base 8

8 Cheeks scaleless; midline of belly scaleless but with a bridge of scales before anus; a prominent suborbital bar; anal fin usually large, the rays long, reaching almost to base of caudal fin; sides with 9 or 10 blotches or bars. .... RIVER DARTER, *Percina shumardi* (p. 806)

Cheeks scaled; midline of belly scaled; suborbital bar present; anal fin not unusually large, not reaching to caudal base; sides with a series of black, oblong, confluent blotches, and continuous with a black band that extends across gill-cover and around snout. .... BLACKSIDE DARTER, *Percina maculata* (p. 803)

9 Premaxillaries protractile; 1 thin anal spine; body usually with X–, M–, or W–shaped markings on sides. .... JOHNNY DARTER, *Etheostoma nigrum*[2] (p. 793)

Premaxillaries not protractile, usually bound to snout by fleshy bridge (the frenum) or fused to preorbitals at sides *(E. blennioides)*; 2 anal spines, the first usually stout and stiff 10

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[2] Throughout its North American range ***Etheostoma (Boleosoma) nigrum*** was considered for many years to be represented by 3 subspecies, all of which occurred in Canadian waters, ***E. n. olmstedi*** from Maritime provinces to eastern Lake Ontario drainages, ***E. n. eulepis*** in Great Lakes basin, and ***E. n. nigrum*** from Saskatchewan and Hudson Bay to western Quebec. However, Cole (1967) elevated ***olmstedi*** to full species status but as yet the occurrence of this species ***E. olmstedi*** Storer in Canadian waters is not clearly defined.

10 Gill membranes not obviously joined but meeting in a V over isthmus (*see* couplet 14, p. 31) 11

Gill membranes broadly joined by a sheet of tissue covering isthmus but free from it 13

11 Cheeks scaled (scales sometimes covered lightly with tissue); dorsal soft rays usually 10 or 11; lateral line ending under spinous dorsal fin; 10–12 dark vertical bars on sides, not extending downward to ventral surface; caudal fin distinctly speckled; males colourful in life with blue or green patches between darker bars on sides and blue and red on spinous dorsal fin. .... IOWA DARTER, *Etheostoma exile* (p. 783)

Cheeks naked; dorsal rays usually 12–13, or 8–9; lateral line variously incomplete or absent 12

12 Dorsal rays 12 or 13; dorsal spines 9 or 10; lateral line usually incomplete; 6 dark, vertical bands on body from anus to tail, each extends almost to ventral midline; males colourful in life with green, blue, and orange colouration on head, sides, dorsal, and anal fins. .... RAINBOW DARTER, *Etheostoma caeruleum* (p. 780)

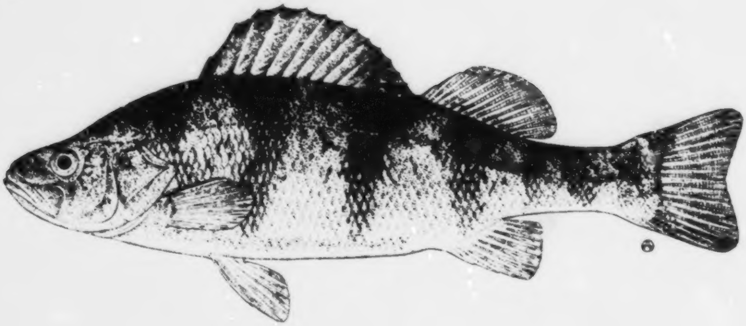
Dorsal rays 8 or 9; dorsal spines 6 or 7; lateral line completely absent or with up to 7 pored scales; sides with 7 or 8 squarish, dark patches on sides; a distinct suborbital bar; caudal fin distinctly barred or speckled. .... LEAST DARTER, *Etheostoma microperca* (p. 790)

13 Dorsal spines 6–8, short, length equal to or shorter than eye diameter, those of males often with fleshy tips; body slender, elongate; head distinctly pointed, mouth terminal; cheeks and opercles naked; colour in life brownish, with 10–12 short, vertical bars. .... FANTAIL DARTER, *Etheostoma flabellare* (p. 787)

Dorsal spines 13, not short, length obviously greater than eye diameter and never with fleshy tips; body robust; snout distinctly rounded, overhanging the small mouth; cheeks and opercles scaled; body greenish in life with V-shaped marks that extend below the midline. .... GREENSIDE DARTER, *Etheostoma blennioides* (p. 777)

YELLOW PERCH

Perca flavescens (Mitchill)



Description Meristics and proportional measurements are for populations from Nova Scotia to Alberta, *see* table in *Systematic notes* for variability. Body elongate, oval rather than tubular or subcylindrical, average length 4–10 inches (102–254 mm), laterally compressed, greatest body depth 16.3–28.1% of total length. Head moderately deep, rounded at tip, its length 23.1–29.3% of total length, narrow, interorbital distance 16.9–27.3% of head length; gill membranes extended forward, not joined, nor broadly joined to isthmus, preopercular bone serrate at least on angle; short spine at tip of operculum; eye diameter 15.8–30.4% of head length (greatest in young); snout moderately long, blunt, not extending beyond lower jaw, its length 23.4–34.2% of head length; premaxillaries protractile; mouth moderately large, terminal, slightly oblique, jaws equal; maxillary extending at least to mid-point of eye; teeth in brushlike bands on jaws, palatines and vomer, small, decreasing in size posteriorly, no canines. Gill rakers fine, comblike, and usually 12–16 on lower limb, 4–8 on upper limb. Branchiostegal rays 6:7, 7:7, 7:8 or 8:8, usually 7:7. Fins: dorsals 2, obviously separated, first dorsal spiny, high, rounded, spines strong, usually 13–15, second dorsal smaller, but of about same height, with 1 or 2 spines and 12–15 rays; caudal peduncle long and narrow; caudal shallowly forked, tips rounded; anal with 2 spines and 6–8 rays, fin about ½ size of second dorsal, square to rounded; pelvics thoracic, space between them less than ½ base of 1 fin, moderate length, a little longer than pectoral fins, square, 1 spine and 5 rays; pectorals broad, rounded, 13–15 rays. Scales ctenoid, cheeks scaled, opercles mostly naked, breast and belly scaled; lateral line complete, high, little arched, scales 51–61, usually 53–57. Peritoneum silvery; intestine well differentiated, 3 short, thick pyloric caeca. Vertebrae 38–41.

No nuptial tubercles.

Colour Variable with size and habitat; dorsal surface of back and head bright green to olive, to golden brown; sides to below pectoral fins yellow-green to yellow, the colour of the back extending down sides in about seven tapering bars; eye yellow to green; ventral surface of head and body grey to milk-white, dorsal and caudal fins yellow to green, edge of first dorsal often black, black on membranes between spines 1 and 2 and last four or five membranes in adults, anal and pelvic fins opaque, yellow to silver white, pectoral fins amber and transparent. Colours of spawning males more intense, bronze-green, bright yellow, bars darker, lower fins suffused with orange to bright red, females less highly coloured. The young are transparent, then silvery or dull pale green.

At times strikingly coloured individuals are seen. These are grey-blue or red, lack bars, and result from the dominance or absence of some part of the pigment compliment (*see* Dymond 1932b; Crossman 1962e). *See* colour illustration facing p. 730.

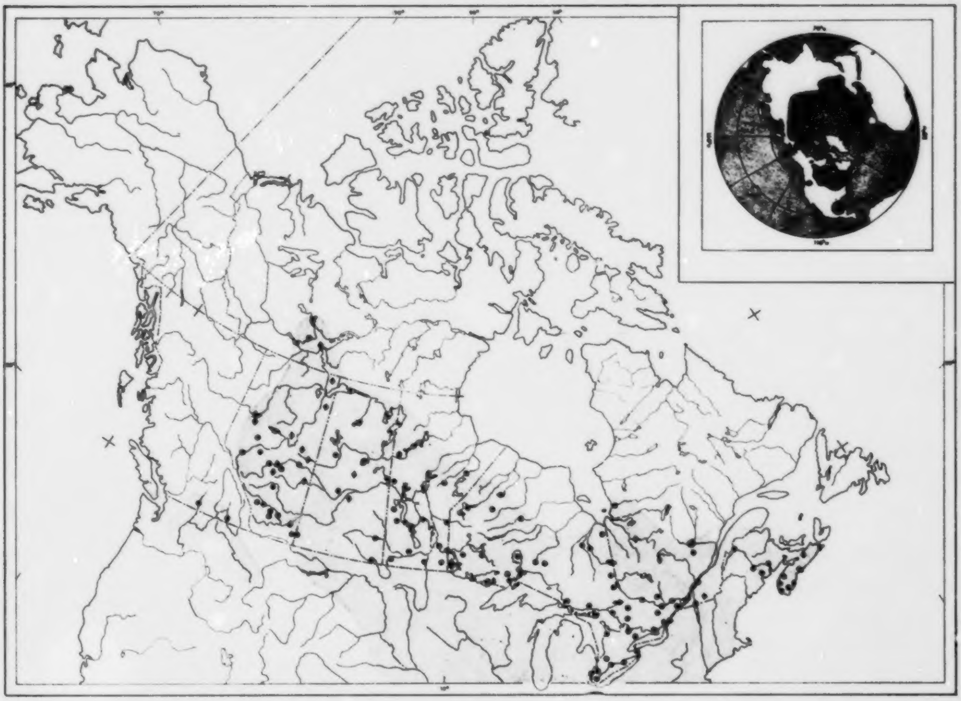
Systematic notes The perch of Eurasia and the yellow perch of North America have long been considered distinct species, *P. fluviatilis* the perch, and *P. flavescens* yellow perch. A study, published in 1963, by the Russian scienists Svetovidov and Dorofeeva concluded that there was a single, circumpolar species, for which the older name *P. fluviatilis* should be retained. They designated three subspecies, *P. f. fluviatilis* (Eurasia generally), *P. f. intermedius* (Kolyma River, Siberia), and *P. f. flavescens* (North America). This has been accepted by some North American authors (Scott and Crossman 1967; McPhail and Lindsey 1970) but rejected by others (Bailey et al. 1970) on the basis that the data (very few yellow perch examined) was not conclusive. Lack of conviction in the evidence presented, the discontinuous distribution, and differences in growth rate, body form and colour, have led to a feeling that the original name should be retained for such a well-known fish until the evidence is more convincing.

McPhail and Lindsey (1970) gave details of postglacial dispersal from the Mississippi River. The only meristic trends east to west or north to south in Canada in the material examined (*see* following table) were a slight tendency toward one more dorsal spine west from western Ontario and a slight shift westward toward fewer lateral line scales. Re-examination of yellow perch from Lake Nipigon yielded second dorsal spines counts of 2 and rarely 1, rather than the unique "3 and rarely 2" of Dymond (1926). Driver and Garside (1966) reported on the effect on meristics of this species of salinities approaching ⅓ sea water in saline lakes in Manitoba. They concluded that it was not as great as would be expected and difficult to separate from that resulting from differences in water temperature of the different habitats.

Distribution The yellow perch and the Eurasian perch combined have an almost circumpolar distribution in the fresh waters (and rarely in brackish waters) of the northern hemisphere. The yellow perch occurs in North America, from Nova Scotia south along the Atlantic coast, previously to South Carolina now apparently to the Florida panhandle and Alabama, west on the west side of the Appalachian Mountains from western Pennsylvania to upper Missouri, from eastern Kansas northwest to Montana, north to Great Slave Lake, southeast to James Bay, Quebec, and New Brunswick. This species has been introduced into almost all the states to the west and south of this general area, including Washington, Oregon, California, Utah, New Mexico, and Texas.

	Dorsal fins									Anal fin					
	Spines of first dorsal					Rays of second dorsal				Spines			Rays		
	11	12	13	14	15	12	13	14	15	1	2	3	6	7	8
N.S.	–	6	1	–	–	–	4	2	–	–	6	–	2	4	–
N.B.	–	9	7	–	–	–	11	7	–	–	29	–	1	17	1
Que.	–	2	8	–	–	–	8	2	–	–	10	–	–	7	3
Ont.															
L. Simcoe	–	1	6	–	–	5	2	–	–	–	7	–	–	5	2
L. Nipissing	–	4	6	–	–	3	7	–	–	–	10	–	–	4	6
Kenora Dist.	–	–	1	8	–	1	8	–	–	–	9	–	–	6	3
Man.	3	33	8	–	–	4	19	11	1	–	10	–	–	2	8
Sask.	–	–	1	6	–	1	6	–	–	–	7	–	–	7	–
Alta.	–	–	3	5	–	–	3	5	–	–	8	–	–	6	2

	Pectoral rays			Branchiostegal rays				Lateral line scales											Vertebrae			
	13	14	15	6,7	7,7	7,8	8,8	51	52	53	54	55	56	57	58	59	60	61	38	39	40	41
N.S.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	4	–
N.B.	–	–	–	–	7	2	1	–	–	1	1	–	1	3	2	1	–	1	–	3	8	9
Que.	–	–	–	–	11	1	–	–	–	–	–	–	–	–	–	–	–	–	2	9	1	–
Ont.																						
L. Simcoe	4	3	–	–	–	–	–	–	–	–	1	2	2	1	1	–	–	–	1	6	1	–
L. Nipissing	–	–	–	–	11	–	–	–	–	–	–	–	–	–	–	–	–	–	1	10	–	–
Kenora Dist.	–	9	–	–	–	–	–	3	1	6	2	4	1	–	–	1	–	–	–	–	–	–
Man.	–	–	–	1	18	–	–	–	1	4	1	2	–	1	1	–	–	–	2	25	4	–
Sask.	4	3	–	–	–	–	–	–	–	1	2	1	3	–	–	–	–	–	–	–	–	–
Alta.	–	–	–	–	–	–	–	–	–	–	2	1	1	1	–	1	1	1	–	–	–	–



In Canada it occurs from Nova Scotia (not Cape Breton Island) west across New Brunswick to Baie Comeau, Que., across Quebec to James Bay, in Abitibi Lake, west across Ontario at the latitude of the upper Albany River, north through central Manitoba but not to the Hudson Bay coast, through all of Saskatchewan, north to Great Slave Lake, and south through Alberta extending to the foothills in the south. It occurs in British Columbia in the Pend Oreille, Kootenay and Okanagan watersheds as a result of a northward spread from introductions in Washington State.

Biology As a result of its commercial and recreational importance there is considerable literature on various aspects of the life history of the yellow perch, particularly age, growth, and production. Among discussions of populations in Canadian habitats are those of Harkness (1922), Carlander (1950b), Lawler (1953), Scott (1955), Ferguson (1958), Coble (1966), Sheri and Power (1969c). There are many more on United States populations, especially Harrington (1947b), several by Jobes and Hile (*see* Jobes 1952), Herman et al. (1959), and Muncy (1962).

The yellow perch spawns in the spring, usually from April 15 to early May, but spawning may extend into July in some areas. Water temperatures of 44°–54° F (6.7°–12.2° C) have been cited. Adults migrate shoreward into the shallows of lakes, and often into tributary rivers to spawn. Where this species occurs in brackish water, they move up into fresh water to spawn. The smaller males move to the spawning grounds first, are followed by the females, and males remain longer on the spawning grounds than do the females. Spawning takes place during the night and early morning, usually near rooted vegetation, submerged brush, or fallen trees, but at times over sand or gravel. The actual spawning act appears to be undocumented but thought to involve a single larger female and many males which swim about in a long, compact queue, the first males with their snouts pressed against the female. Total number of eggs per female increases with size and has been reported at 36,600–109,000 for fish 6.8–10.0 inches (147–254 mm) total length in Maryland, and 3035–61,465 for females 5.1–10.1 inches (131–257 mm) fork length in Lake Ontario. No nest is built. The transparent eggs, which when shed and swollen are usually 3.5 mm in diameter, are extruded in a unique, transparent, gelatinous, accordion-folded string or tube. This mass, which may be as long as 7 feet (2.1 m), as wide as 2–4 inches (51–102 mm) and weigh up to 2 pounds, may contain 2000–90,000 eggs with an average of about 23,000 eggs. Aeration of the eggs is accomplished by means of water circulation through holes and a central canal. These egg masses are semi-buoyant. They undulate with water movement and adhere to submerged vegetation or, at times, to the bottom. They can be easily cast ashore by wind, waves, and current and lost. No protection is given the egg masses or young by the parents. Hatching usually takes approximately 8–10 days, but has been reported to take as long as 27 days at 47° F (8.3° C). The young, when they hatch, are transparent, about 5 mm in length and have 16–21 postanal myomeres. They are inactive for about 5 days during the absorption of the yolk. Early development was given in detail by Fish (1929, 1932) and by Mansueti (1964). Means of separating the superficially similar young of this species and the walleye were given by Norden (1961b).

Growth is rapid at first. Trautman (1957) said yellow perch in Ohio in October were 1.8–4.0 inches (46–102 mm) long. In the first summer large, compact schools of young are often seen. Growth is extremely variable depending on population size, habitat size, and productivity. Ages are usually determined from scales in North America and by scales or opercles in Europe. The validity of the scale method of aging, and the body-scale size relation, were described for Lake Michigan by Jobes (1952) and Joeris (1957). The following table, giving age–length and age–weight relations for various Canadian habitats, exhibits this variability. Yellow perch 2 years and older were, on the average, 3 inches (76 mm) longer in Lake Erie and Lake Ontario than they were in Lake Jesse, N.S.

Stunting often occurs in crowded populations with adults never exceeding 6 inches (152 mm) in length.

Females grow faster than males even at age 1 and achieve a greater ultimate size. Northern populations grow more slowly and live longer. Sexual maturity is usually achieved

		Age									
	FL	0+	1+	2+	3+	4+	5+	6+	7+	8+	9+
Lake Jesse,	*inches*	1.4	3.0	3.6	4.3	4.9	–	–	–	–	–
N.S.	*mm*	36	77	92	108	125	–	–	–	–	–
(Smith 1939)	Wt (*oz*)	.02	.19	.29	.49	.78	–	–	–	–	–
Bay of Quinte,	FL										
L. Ontario	*inches*	–	–	6.2	6.8	7.2	8.0	8.5	8.2	10.1	–
(Sheri and	*mm*	–	–	158	172	182	202	216	209	257	–
Power 1969c)	Wt (*oz*)	–	–	2.3	3.0	3.8	4.5	6.0	5.0	10.9	
	TL										
Lake Erie,	*inches*	–	–	6.6	7.7	8.5	9.9	10.8	11.0	–	–
Ont.	*mm*	–	–	168	196	216	251	274	279	–	–
(Harkness 1922)	Wt (*oz*)	–	–	1.5	4.3	5.7	9.2	11.6	12.8	–	–
	FL										
Heming Lake,	*inches*	1.9	2.8	3.4	4.9	5.6	6.7	8.4	9.1	10.2	11.9
Man.	*mm*	48	71	86	124	142	170	213	231	259	302
(Lawler 1953)											

by males at 3 years and females at 4 years of age. Yearling males in Lake Erie are often fertile. Maximum age is usually 9 or 10 years but a female from Lake Erie, 12.2 inches (310 mm) in total length, which weighed 0.78 pounds, was aged at 11+ years. Yellow perch in Ontario are most often 4–10 ounces but one taken in Baie du Doré, Lake Huron, was 14.3 inches (363 mm) in length and weighed 1 pound 8 ounces. Weights to 3 pounds have been reported from Lac la Biche in Saskatchewan, and 2 pounds 3 ounces from Baptiste Lake in northern Alberta. Another Alberta perch, from Tucker Lake, was 15 inches (381 mm) in fork length and weighed 2¼ pounds. In 1935, Ontario commercial fishermen reported maximum size for Lake Erie as 13$\frac{3}{16}$ inches (334 mm) and 1 pound 1 ounce. A 14-inch (356-mm) perch was taken in the Saugeen River (Lake Huron) in 1929, and one weighing 4 pounds 1 ounce was caught in Quebec. Trautman (1957) gave maximum size for Ohio as 13.5 inches (343 mm) and 1 pound 5 ounces. The present angler record is an individual 4 pounds 3½ ounces in weight which was caught in New Jersey in 1865. Yellow perch caught by anglers in Canada are usually 8–12 inches (203–305 mm) in length.

Yellow perch are very adaptable and able to utilize a wide variety of warm to cooler habitats from large lakes to ponds, or quiet rivers. They are most abundant in the open water of lakes with moderate vegetation with clear water and bottoms of muck to sand and gravel. Numbers will decrease in a body of water in which turbidity increases or vegetation decreases. The yellow perch is a freshwater fish but it is found in brackish water along the Atlantic coast and in saline lakes in the Prairies (to 10,300 ppm total dissolved solids). McKenzie (1959) recorded their capture near Newcastle, N.B., in the brackish water of the Miramichi River, in early summer during the American shad and alewife fishery. Salinities at Newcastle, on July 15, 1956, were 15‰ at the bottom and 6‰ at the surface. The yellow perch is apparently more tolerant of low oxygen than sunfishes. In nature yellow perch are usually found at temperatures of 66.2°–69.8° F (19°–21° C) (Ferguson 1958). Seasonal vertical movements suggest they move to follow the 68° F (20° C) isotherm. Upper lethal temperature has been experimentally determined at 79.7° F (26.5° C) in British Columbia and at 92° F (33° C) elsewhere. Final temperature preference has been experimentally determined at 69.8°–77.0° F (21°–24° C).

They are usually considered shallow-water fishes and are usually not taken below 30 feet (9.2 m) but they have been taken as deep as 150 feet (45.7 m) in May. Adults and young are gregarious, often moving about in loose aggregation of 50–200 individuals, segregated by size. The young, in shallower water and nearer shore than the adults, are often in mixed schools which include many individuals of a species of minnow, such as the spottail shiner. The discrete schools of adults are close together in summer and more separated in winter. Yellow perch are inactive at night and rest on the bottom. There are migratory movements in the spring, movements inshore and out, up and down over the day, and seasonal movements out of and into deeper water in response to temperature, and probably, to distribution of food. Yellow perch are active all winter under the ice in shallow water or in deeper water (*see* Scott 1955; Hergenrader and Hasler 1968, for greater detail).

The food of the yellow perch has been extensively studied in Canadian habitats (*see* Tharratt 1959; Keast and Webb 1966; Keast and Welsh 1968; Keast 1968b). Food changes with size and season but is largely immature insects, larger invertebrates, and fishes, taken in open water or off the bottom. In Lake Opinicon, Ont., the young feed on cladocerans, ostracods, and chironomid larvae. By the end of their first year, they have shifted to Odonata nymphs (to 40% volume), Ephemeroptera (30%), molluscs (35%), ostracods (30%), chironomid larvae (30%), and small fishes (30%). Fish over 6 inches (150 mm) length feed on decapods (to 70%), small fishes (75%), and Odonata nymphs (40%). Yellow perch apparently prey on the eggs and young of a wide variety of fishes.

Active feeding takes place morning and

evening (7 AM to 6 PM), with little to none at night. Food is actively taken all through the winter, and may include fish eggs. Feeding is said by some to be suspended just prior to spawning, but others say anglers catch large numbers during the spawning run using minnows as bait.

The yellow perch is preyed on by almost all other warm to cool water predatory fishes such as basses, sunfishes, crappies, walleye, sauger, other yellow perch, northern pike, muskellunge, and to some extent, lake trout. Even the adults do not escape this predation. Water birds such as gulls, mergansers, loons, and kingfishers eat this perch. The young and adults may compete for food with brook trout, ciscoes, lake whitefish, basses, crappies, and bluegill. Their high reproductive potential, voracious appetite, and effectiveness at feeding can in some places lead to serious competition with more valued species, such as trout and basses, and with themselves. Those characteristics are probably the cause of the many populations of stunted yellow perch.

A wide variety of parasites afflict this fish. Parasites listed by Hoffman (1967) for the whole of its range were as follows: protozoans (16), trematodes (52), cestodes (11), nematodes (17), acanthocephalans (10), leeches (6), molluscs, crustaceans (8).

Guilford (1963) described three new species of Myxosporidia, *Myxosoma neurophila, M. scleroperca*, and *Henneguya doori*, from yellow perch in Lake Michigan. Tedla and Fernando (1969a) reported in great detail on the external and internal parasite fauna of this species in Lake Ontario, and seasonal changes in incidence and intensity of infestations. The same authors (1969b, c, 1970) discussed copepod parasites and gill parasites of this species. Lawler (1969) dealt with the effect on perch of the parasite *Triaenophorus nodulosus*. Dechtiar and Loftus (1965), Bangham and Hunter (1939), Bangham and Venard (1946), Bangham and Adams (1954), and Bangham (1955) gave lists of the parasites of this species in Canadian habitats. Other than the growth reducing or mortality factors exerted by many species of parasites, parasites of the yellow perch which are of more direct interest to man are black-spot, yellow grub, and the broad tapeworm *Diphyllobothrium latum*. The first two, although harmless to man, render the fish unsightly and often cause an angler to discard his catch. The last is a parasite which could infect man if raw, or poorly cooked, infected fish were eaten. Yellow perch suffer as well from a number of fish diseases and such pathological conditions as tumors.

Relation to man The yellow perch has long been of prime importance to man. It inhabits a vast territory, a wide variety of habitats, is a schooling fish, and congregates near shore in the spring. All of these factors make it readily available to fishermen, both commercial and recreational. It is an active feeder the whole of the year so can be angled summer and winter. The yellow perch is a sport fish of variable importance from the Maritimes to British Columbia. It is taken commercially from Ohio to Alberta. Its flesh is white, flaky, delicious, and popular. This species is sold, fresh and frozen, almost everywhere. It was one of the first species to be exploited in the mid- to late 1800's by the seine fishery of the Great Lakes. Production, commercial landings, and price paid for this fish, depend on a wide variety of factors such as varying year-class strength, availability of more favoured species, availability of fishermen, presence or absence of predators, and temperature and food-dependent growth rate. The Great Lakes are the major producers of yellow perch and catches there have, at various times, suffered from all these effects. This leads to a widely fluctuating fishery. Of the total yearly production in Canada, the Great Lakes contribute all but about 1 million pounds. Annual catches varied from a low of approximately 16.5 million pounds in 1919 to a high of 72.1 million pounds in 1934, to an all time low of 3.2 million pounds in 1948, to another high of nearly 27 million pounds in 1968. The dominance of the Great Lakes is obvious from the fact that commercial fishermen in Lake Erie alone (Canada and United States) recently harvested 30 million pounds worth 3.2 million dollars. Price fluctuations have been such that the greatest catch did not always yield the greatest return, and the price is now stabilized largely by federal price support funds. The Ontario catch in 1968 was 24,968,515 pounds, worth $2,107,470. Of this, Lake Erie contributed 24,435,187 pounds (97%). The next largest catches were from lakes Ontario, Huron, and St. Clair. The Freshwater Fish Marketing Corporation listed prices per pound for yellow perch, in November, 1970, as 40¢ (over ¾ pound) and 30¢ (under ¾ pound).

Anglers usually catch yellow perch, summer and winter, by still fishing for them with minnows, worms, or cut fish as bait. The problem of bait for the winter fishery is solved by freezing or salting minnows when they are available. They do not fight hard, but the challenge of catching a species which bites so lightly, the possibility of large catches and the high quality of their flesh compensate for this. There is generally no size or bag limit for anglers.

Yellow perch are used as live bait for other fishes such as northern pike and muskellunge and as cut bait for a variety of other fishes. Use of the young as live bait is often restricted to the water in which they were captured.

The yellow perch is the study animal most commonly used to familiarize students with the internal and external anatomy of a teleost fish.

Nomenclature

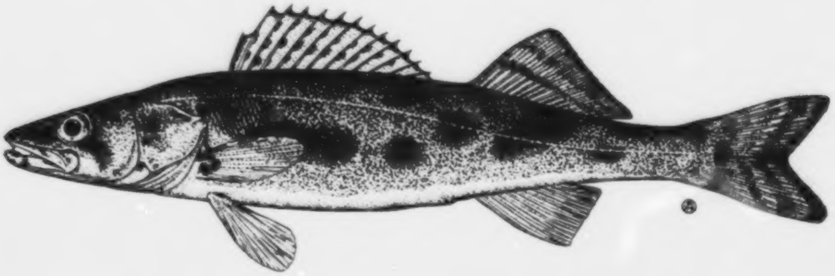
Morone Flavescens — Mitchill 1814: 18 (type locality New York)
Perca notata — Rafinesque 1818b: 205
Perca acuta — Cuvier and Valenciennes 1828: 49
Perca flavescens (Cuvier) — Richardson 1836: 1
perca fluviatilis — Perley 1852: 82
Perca americana — Wright 1892: 453
Perca americanus Schranck — Cox 1896b: 70
Perca flavescens (Mitchill) — Evermann and Goldsborough 1907a: 108
Perca fluviatilis Linnaeus — Scott and Crossman 1967: 21
Perca flavescens (Mitchill) — Scott and Crossman 1969: 23
Perca fluviatilis flavescens (Mitchill) — McPhail and Lindsey 1970: 343

Etymology *Perca* — dusky, and possibly the ancient common name of the Eurasian perch; *flavescens* — yellow.

Common names Yellow perch, perch, lake perch, American perch. French common name: *perchaude*.

SAUGER

Stizostedion canadense (Smith)



Description Meristics and proportions for populations from Ontario and Saskatchewan. Body elongate, almost to quite cylindrical, average length 10–16 inches (254–406 mm), little or no lateral compression, greatest body depth at last half of first dorsal fin 12.6–16.4% of total length; caudal peduncle of moderate length, shallow, round. Head not deep, a blunt point at tip, its length 18.0–26.3% total length (greatest in young), moderately wide, interorbital distance 13.0–23.3% of head length (least in young), gill membranes extended forward, not joined nor broadly joined to isthmus; preopercle strongly serrate at least at bottom; short spine at upper edge of tip of opercle; eye large, diameter 17.8–25.5% of head length (greatest in young); snout long, pointed, not extending beyond upper jaw, its length 27.8–31.6% of head length; premaxillaries protractile; mouth large, terminal, very slightly oblique, jaws equal; maxillary very long, extending to posterior edge of pupil; teeth on jaws, head of vomer, and palatines numerous, longer, and sharp, large canines (often recurved) on vomer, palatines, and jaws; pharyngeal teeth large, sharp, recurved. Gill rakers moderately long and tooth bearing, inner edge of gill arch has short, rounded, tooth-bearing knobs, usually 6–8 rakers on lower limb, 3–5 on upper limb, but given by Paetz and Nelson (1970) as 15 and 6 for Alberta. Branchiostegal rays 6–8, 6:7, 7:7 or 7:8 (usually 7:7). Fins: dorsals 2, obviously separated, first dorsal spiny, high, long, a rounded triangle in shape, strong spines 13–15 (usually 14), second dorsal as high or higher but base a little shorter, with 1 (rarely 2) fine spine and 16–21 rays (usually 18), square to slightly emarginate; caudal of moderate size, long, not overly broad, well forked, tips rather pointed; anal with 2 spines and 11–14 rays, height greater than base, smaller than second dorsal, square; pelvics thoracic, under pectorals, widely spaced, space more than base of 1 fin (fin base is 45.7–56.7% of interfin space), long, equal to or longer than pectorals, tip rounded, 1 spine and 5 rays; pectoral fins only moderately broad, tips rounded, 12–14 rays (usually 13). Scales strongly ctenoid, cheeks mostly scaled, opercle mostly naked, breast and belly normally scaled; lateral line complete, high, slightly curved, scales rather small, 82–100 (usually 88–95) including 3 or 4 pitted scales in the area where the lateral line extends onto the scaled base of the caudal fin. Peritoneum white, intestine well differentiated, pyloric caeca 3–9 but usually 4–6, and each usually shorter than stomach; ovaries of post-spawning females reddish purple. Vertebrae 43–45.

No nuptial tubercles.

Colour Variable with habitat and, to a lesser extent, size. Background colour most often sandy or dull brown (but at times dull grey) with darker brown markings, markings usually absent on saugers from clear water; dorsal surface brown, sides paler, back with three or four dark brown saddles, some of which expand horizontally on sides, sides also with several large, round spots, ventral surface milky white; head with dark bars, eye silvery from light reflected by special light sensitive layer *(Tapetum lucidum)*; first dorsal fin with dark pigment on edge of membranes and rows of distinct black spots below (faint to absent in young), no dark blotch at posterior base; second dorsal with two narrow, dark bands of spots on membranes; caudal fin with rows of dark brown bars, lower lobe sometimes with faint white tip; anal fin white with dark speckles, sometimes with white tip, pelvic fins white with dark speckles; pectoral fins clear amber, with a black spot at base. Young with sandy-coloured background and conspicuous, dark brown, almost continuous saddle under dorsal fin.

Systematic notes Counts and proportions often considered stable over range. The sauger of the Great Lakes was at one time called *S. griseum* or *S. c. griseum*, and that of the St. Lawrence, *S. c. canadense*. There is still some tendency to consider the sauger as two subspecies, *S. c. canadense*, and *S. c. boreum* of the upper Missouri River. The following differences existed between counts for material examined for this account and those given (for Alberta?) by Paetz and Nelson (1970) and for Ohio by Trautman (1957):

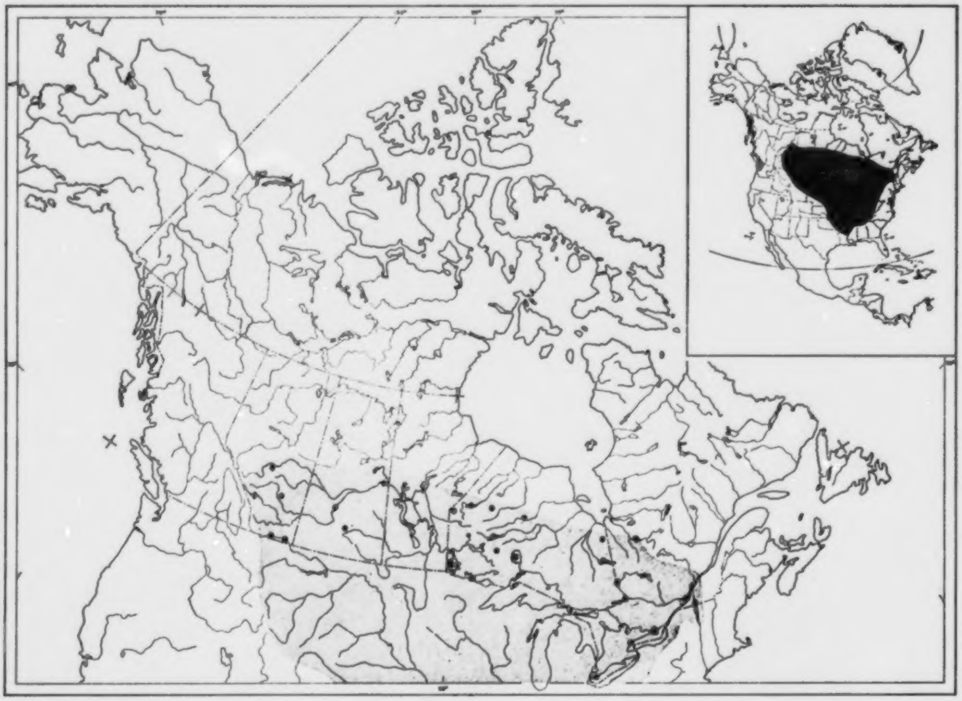
	Ont.	Sask.	Alta.	Ohio
Spines				
dorsal 1	13–15	13–14	10–14	10–14
dorsal 2	1(rarely 2)	1	2	1
Rays				
dorsal 2	16–20	18–19	17–22	17–22
Pyloric caeca	4–6	–	3–9	5–8
Lateral line scales	82–100	89–95	80–90	–

Variation within populations may be as great as differences given for populations in various areas. In many areas this species is probably mistaken for small walleyes.

Distribution The sauger is restricted to the freshwaters (and rarely brackish water) of North America. It occurs from the St. Lawrence–Champlain system south, west of the Appalachian Mountains to the Tennessee River in Alabama, southwest to northern Louisiana, northwest through eastern Oklahoma to central Montana and central Alberta, east below James Bay to Quebec.

In Canada it occurs from Quebec, in the St. Lawrence–Champlain system (and rarely downstream to brackish water, Vladykov 1949c), northward east of the Ottawa River almost to James Bay, west across Ontario south of a line from Kesagami Lake to Sandy Lake, in Manitoba south of the upper end of Lake Winnipeg, in the southern half of Saskatchewan, and north in Alberta to the North Saskatchewan River. Many recent texts (i.e., Moore 1968) repeat the statement of Hubbs and Lagler (1941–1964) that the sauger occurs in New Brunswick. There is no evidence to support this (Scott and Crossman 1959).

Biology The biology of this species in Canada is not well known. Various facets of its life history in Canada were described by Hart (1928), Doan (1941), Kennedy (1949a), and Stewart (1964). Information on United States populations came from Carlander (1950b), Carufel (1963), Priegel (1969), and Nelson (1968a). Spawning takes place for about a two-week period in the spring, often immediately after the walleye, usually the last week in May or first week in June. Both species may utilize the same shoals of gravel to rubble in large turbid lakes or turbid rivers. Spawning has been reported to begin at 39° F (3.9° C) and 43° F (6.1° C). The males arrive on the spawning ground first and are followed by the females which leave very soon after spawning. Spawning occurs at night in water 2–12 feet (61–366 cm) deep. The female is usually attended by one or more smaller males. The eggs are slightly



larger than 1.44–1.86 mm (size of embryo). Ripe eggs have been reported to be 1.0–1.5 mm in diameter and smaller than those of the walleye. The eggs are sticky when laid, but after water hardening are semibuoyant and non-adhesive. No nest is built, the eggs are shed, fertilized, and fall to the bottom where they drop between the gravel or boulders. Females will lay from 15,000–40,000 eggs per pound of fish depending on size. Total number of eggs per female has been variously given as ranging from approximately 9000 to 96,000. Hatching occurs over a range of 25–29 days at temperatures from 40°–55° F (4.5°–12.8° C). At hatching, the young are 4.5–6.2 mm long. An additional 7–9 days is spent on the bottom absorbing the yolk. The young have 21–26 postanal myomeres. The early development of this species was treated by Fish (1932), and Nelson (1968b) gave details of development and means of separating the very young of sauger and walleye.

Growth is rapid in the first year but slower than that of walleyes in the same waters. Rate of growth is variable with location, and is faster in prairie lakes than in those of the Precambrian Shield. Trautman (1957) said that in Ohio young-of-the-year in October were 3–6 inches (76–152 mm) in length. Age can be determined from scales and the body-scale size relation was determined by Priegel (1969). The following table gives the age–length (average calculated total length at end of year) relation, as converted by Priegel, and the age–weight relation, for saugers from three habitats.

Many sauger populations in northern Precambrian Shield lakes exhibit extremely slow growth, live longer, and reach an upper ultimate length of about 9 inches (229 mm). It is unlikely that any Canadian saugers surpass 21 inches (533 mm) total length, or 2 pounds weight. They grow at least to 19 inches (483 mm) in Alberta. Trautman gave maximum in Ohio as that of a gravid female which was 19.3 inches (490 mm) in length and a weight

Age	Lake Erie (Deason 1933) TL		Lake Nipigon (Hart 1928) Length		Wt	Lake of the Woods (Carlander 1950b) FL		Wt
	(inches)	*(mm)*	*(inches)*	*(mm)*	*(lb)*	*(inches)*	*(mm)*	*(lb)*
1	3.9	99	–	–	–	6.6	168	0.13
2	7.9	201	–	–	–	7.7	196	0.16
3	10.4	264	9.4	239	0.22	10.4	264	0.48
4	12.2	310	10.4	264	0.25	12.5	318	0.67
5	13.6	345	12.3	312	0.56	13.7	348	0.81
6	15.8	401	12.5	318	0.56	14.2	361	0.96
7	–	–	13.1	333	0.59	15.1	384	1.17
8	–	–	14.5	368	0.94	15.5	394	1.26
9	–	–	15.4	391	1.17	16.7	424	1.62
10	–	–	13.7	348	0.97	15.7	399	–
11	–	–	15.1	384	0.88	–	–	–
12	–	–	16.5	419	1.25	–	–	–
13	–	–	16.5	419	1.44	–	–	–

of 3 pounds 3 ounces. He said some of the larger specimens recorded may have been sauger × walleye hybrids. The present angler record is a sauger 28 inches (711 mm) long, which weighed 8 pounds 5 ounces, and was caught in the Niobrara River, Nebraska (Garrison Dam, Missouri River?) in 1961 (possibly a hybrid?). Maximum age in the north can be as high as 12 or 13 years but in the south it often does not exceed 5–6 years. Sexual maturity is achieved by males at 2–3 years, and by females at 4–6 years of age. The number of individuals of the oldest 2 or 3 years is usually extremely small.

Saugers may be less adaptable than walleyes as habitat preference seems to be for large, shallow lakes which are turbid with colloidal clay suspension, or for large, turbid, slow-flowing rivers. In Lake Nipigon and Lake Superior saugers are restricted to shallow, warm, turbid bays. They are a freshwater fish but are known on rare occasions to descend the St. Lawrence River to a point where the water is usually brackish (Vladykov 1949c).

Although adapted to turbidity, they do not do well unless temperature characteristics allow them to utilize the whole depth range. Turbidity may prevent excessive egg adhesion and thereby reduce suffocation, protect young from predators, and facilitate feeding of the young by concentrating plankton near the surface. In very turbid water saugers usually succeed over walleyes. In Ombabika Bay, Lake Nipigon, a predominantly walleye dominance changed to a sauger dominance in a period of a few years following diversion into the bay of turbid water. Water temperature may limit northward distribution. The lower reaches of such large, slow-flowing turbid rivers in Ontario as the Albany and Attawapiskat do not contain saugers, although they occur in the upper reaches. Northern distribution is apparently related to the 60° F July isotherm (Ryder et al. 1964). The temperature of the water level at which saugers are most often caught in summer is 65.5°–66.6° F (18.6°–19.2° C). Saugers are usually found in the top 20 feet of water but were present in Lake Nipigon in numbers to 45 feet, and more rarely to 63 feet.

Saugers usually move little in the summertime but there are records of individuals moving as far as 100 miles in the Mississippi River. In clearer water they are most active for short periods in the evening and early morning. In more turbid water, where light intensities are lowered, the period of activity is longer. In Canadian habitats, saugers are usually associated with goldeye, walleye, yellow perch, northern pike, and whitefishes.

Saugers are sight predators and negatively phototrophic, the light-gathering effect of the *Tapetum lucidum* of the eyes is a definite advantage in their turbid habitat. They often feed on the same shoals as do walleye. Food is variable with size and changes from zooplankton to chironomid larvae, to immature and adult mayflies. Adults feed on a variety of small fishes and various invertebrates such as leeches, crayfish, and insects. Priegel (1969) analyzed in detail food by size and season. Fry of other fishes are taken by sauger in the 12–50 mm size range. Fishes mentioned as food of the sauger are gizzard shad, trout-perch, white bass, freshwater drum, emerald shiner, black crappie, walleye, sauger, yellow perch, burbot, flathead chub, and sticklebacks. In Wisconsin, winter diet of adults is largely emerald shiners and trout-perch. If these fishes are scarce, then immature insects make up the ration. Sauger have, at times, been considered significant predators on whitefishes. This is apparently not so. It would seem they are not significant predators on any species of importance to man.

Northern pike, walleye, goldeye, and lake whitefish are the chief food competitors of the sauger. The effect of wind, waves, and temperature on hatching success and early growth is a greater control of population size than are competition and predation. Saugers of various sizes are preyed on by sauger, walleye, northern pike, and probably yellow perch.

The 23 parasites of the sauger, over the whole of its range, listed by Hoffman (1967) consisted of trematodes (6), cestodes (6), a nematode, acanthocephalans (2), a mollusc, crustaceans (6), and a leech. Many of the same species are found in the walleye also. Parasites of the sauger from Lake Erie were listed by Bangham and Hunter (1939).

The sauger and walleye are known to hybridize in nature. Artificial reciprocal hybrids of these two species were described by Nelson (1968b).

Relation to man The sauger is an important sport and commercial fish. In Manitoba it ranks third in importance, behind the walleye and whitefish in total value. The average sauger taken in the commercial catch is about 1 pound in weight. Most saugers are captured commercially by gillnets and poundnets. The gillnet fishery exploits fish both summer and winter in Manitoba. Gillnet mesh sizes used for sauger are smaller than those used for walleye, and are often responsible for the capture of many undersize walleye. Ontario and Manitoba contribute the bulk of the catch. At one time 2–6 million pounds of saugers were taken from Lake Erie annually. The catch there reported for 1968 was 70 pounds. The total catch recorded for Canada, 1965–1968, was a low of 2,834,000 pounds in 1967 and a high of 4,833,000 pounds in 1966. Landed values were 441,000 dollars and 1.46 million dollars. The Ontario catch in 1966 was only 59,202 pounds which makes the dominance of the Manitoba catch obvious. The catch in that province ranges between 3 and 5.5 million pounds a year.

The sauger has firm, white flesh which some prefer to the walleye. It is usually sold as fresh or frozen boneless fillets and in 1970 commanded a price of 63¢/pound, unprocessed.

Anglers in Canada do not regularly pursue saugers purposely and when caught they are often thought to be small walleye. Saugers are usually caught still fishing with, or drifting with, live or dead minnows. Trolling, drifting, or casting various bright artificial lures works also.

Nomenclature

Lucioperca Canadensis — Smith *in* Cuvier 1834: 275 (type locality Canada)

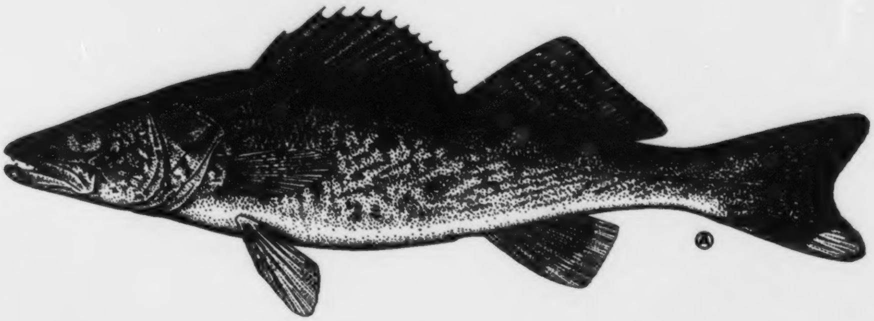
Lucio-perca Canadensis (Smith) — Richardson 1836: 17
?*Lucioperca americana* — Agassiz 1850: 294
Stizostethium Canadense — Bell 1880: 7c
Stizostedion Canadense — Small 1883: 33
Stizostedium Griseum — Small 1883: 33
Stizostedium canadense — Wright 1892: 453
Stizostedion canadense griseum DeKay — Eigenmann 1895: 118
Stizostethium (Cynoperca) canadense (Smith) — Jordan 1877a: 48
Stizostedion canadense (Smith) — Dymond 1926: 80
Stizostedion canadense canadense (Smith) — Hubbs and Brown 1929: 45

Etymology *Stizostedion* — pungent throat?; *canadense* — of Canada, the type locality.

Common names Sauger, sand pickerel, sand pike, sand pike-perch, blue pike, blue pike perch, blue pickerel, grey pike, grey pike perch, grey pickerel. French common name: *doré noir*.

WALLEYE*

Stizostedion vitreum (Mitchill)



Description Meristics and proportions for populations from Ontario to Alberta. Body elongate, subcylindrical when young, average length 13–20 inches (330–508 mm), slightly compressed, more so in large adults in some populations, greatest body depth under anterior half of first dorsal 12.5–19.3% of total length; caudal peduncle moderately long and deep, somewhat compressed. Head deeper than sauger, a blunt point at front, its length 23.8–28.4% of total length (greatest in young), moderately wide, interorbital distance 15.7–21.5% of head length (least in young), gill membranes extended forward, not broadly joined nor broadly joined to isthmus; preopercle bone strongly serrate, serrae sometimes curved forward; opercle with at least one short, sharp spine; eye large (larger in young), diameter 16.1–26.7% of head length; snout long, bluntly pointed, not extending beyond upper jaw, its length 25.3–33.5% of head length; premaxillaries protractile; mouth large, terminal, almost horizontal, jaws equal; maxillary very long, extending to posterior edge of eye; strong teeth on premaxillaries, jaws, head of vomer, and palatines numerous, large, often recurved canine teeth on head of vomer, palatines, jaws, and premaxillaries; pharyngeal teeth large, sharp, recurved. Gill rakers moderately long and tooth bearing on outer edge of gill arch, inner edge has short, rounded, tooth-bearing knobs, 6–8 rakers on lower arch, 4 or 5 on upper arch. Paetz and Nelson (1970) gave gill rakers of 7–14 + 6–8 for Alberta and McPhail and Lindsey (1970) cited 12–15 + 4–5 (counting both sides of lower limb?). Branchiostegal rays 7,7 or 7,8. Fins: dorsals 2, obviously separated, first dorsal spiny, high, long, rounded, strong spines 12–16 (usually 14), second dorsal as high or higher, with 1 fine spine and 18–22 rays (usually 19–21), square to slightly emarginate; caudal long, not overly broad, well forked, tips rounded points; anal with 2 spines and 11–14 (usually 12 or 13) soft rays, height little greater than base, not as long as second dorsal, square; pelvics thoracic, widely spaced, base of 1 fin 58.2–74.6% of space between fins, length about equal to pectoral fins, tip rounded, 1 spine and 5 rays; pectorals only moderately broad, tips rounded, 13–16 (usually 14) rays. Scales strongly ctenoid (*see* Priegel 1964, for development of scales), cheeks scaleless or slightly scaled, opercles mostly naked, breast and belly normally scaled; lateral line complete, high, little curved, lateral line scales rather small, 83–104 (usually 86–92) including 3 or 4 pitted scales of the lateral line which extend on to the base of the caudal fin. McPhail and Lindsey (1970) extend the number to 108. Peritoneum white, short intestine well differentiated, pyloric caeca usually 3, each about same length as stomach; ovaries of post-spawning females reddish-purple. Vertebrae 44–48.

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*Mr R. A. Ryder, Ontario Ministry Natural Resources, prepared outlines on which much of the write-ups for this species and that for the sauger were based. He will be publishing expanded versions on these two species in Ontario.

No nuptial tubercles. Differentiation of sexes difficult.

Colour Highly variable with habitat and to lesser extent with size. In turbid water paler and less marked with obvious black pattern, in clear water more vividly marked. Background usually olive-brown, to golden brown, to yellow, dorsal surface of head and back darker, sides paler, often with golden flecks on scales, ventral surface milk-white or yellow-white. In smaller fishes, 4–14 inches (102–356 mm), vague to obvious, dark, vertical bands across back and down sides, usually absent in adults; dorsal fin dusky, clear or vaguely speckled, no definite rows of spots, noticeable black blotch at base of last few membranes (except in very small); second dorsal and caudal fins with speckles or tiny spots in rather regular rows, lower lobe of caudal and tip of anal fins milk-white; pelvic fins yellow or orange-yellow; pectoral fins dark or pale olive, with dark blotch at base; eyes silvery from light reflected by light sensitive layer (*Tapetum lucidum*).

Grey-coloured walleyes (called "hards" in Lake Erie), which are the result of a bluish colour of the mucus, occur with varying frequency in most populations. Individuals of a slightly bluer colour occur in Lake Nipissing (*see* section on blue walleye in *Systematic notes*). Infrequently orange coloured mutants are taken in Ontario.

The blue walleye of lakes Erie and Ontario was distinguishable from the yellow walleye, and from these grey-blue forms, in that it was more slate-blue or steel-blue on the dorsal surface, ice-blue to silvery on the sides, and silvery to white on the ventral surface. The pelvic fins were white.

Systematic notes Variability of characters within populations is possibly as great as between populations, and characters may be rather stable over the total range of the material examined (*see* following table). Genotypic variability is apparently greater with at least three major genetic types existing in Canadian waters (*see* Uthe and Ryder 1970, for details).

This species consists, or did until recently, of two subspecies, the yellow walleye, *Stizostedion v. vitreum* and the blue walleye, *Stizostedion v. glaucum*. The blue walleye (or blue pike of the Lake Erie fishermen and the trade) was originally described by Hubbs (1926) as a separate species *Stizostedion glaucum*, but the number of fish considered to be intergrades between the two walleyes led to the change to subspecific status. The blue walleye was placed on the "Rare and Endangered" list (McAllister 1970) as "rare or perhaps even extinct." In spite of periodic reports of supposed blue walleyes it has now apparently totally disappeared from lakes

	Spines										Rays																				
	1st dorsal					2nd dorsal					Anal				Pectoral				Lateral line scales												
	12	13	14	15	16	18	19	20	21	22	11	12	13	14	13	14	15	16	83	84	85	86	87	88	89	90	91	92	93	94	104
Peterborough, Ont.	–	–	4	5	–	–	2	4	3	–	1	–	7	1	4	5	–	–	–	–	1	2	1	2	–	2	1	–	–	–	–
L. Erie	1	7	2	–	–	1	2	5	2	–	1	7	2	–	–	–	–	–	3	–	1	3	2	–	–	1	–	–	–	–	–
L. Nipissing	–	5	5	–	–	–	8	2	–	–	–	7	3	–	–	–	–	–	–	–	–	2	1	–	1	2	–	–	–	–	–
L. Superior	–	2	7	1	–	–	–	1	6	3	–	4	6	–	6	4	–	–	–	–	1	1	1	–	–	–	4	2	–	–	1
Savanne L. (Hudson Bay system)	–	–	6	3	1	–	2	2	5	1	1	3	5	–	–	–	8	1	–	–	–	–	1	2	–	1	2	2	1	1	–
Sask.	–	3	5	2	–	–	6	4	–	–	–	5	5	–	–	–	–	–	1	–	1	–	2	3	2	1	–	–	–	–	–
Alta.	–	–	4	–	–	4	–	–	–	–	–	3	1	–	–	4	–	–	–	–	–	–	1	–	1	1	–	1	–	–	–

Erie and Ontario. Consequently, it will not be treated here as a distinct entity but various comments will be made throughout the discussion of the yellow walleye, the only remaining walleye.

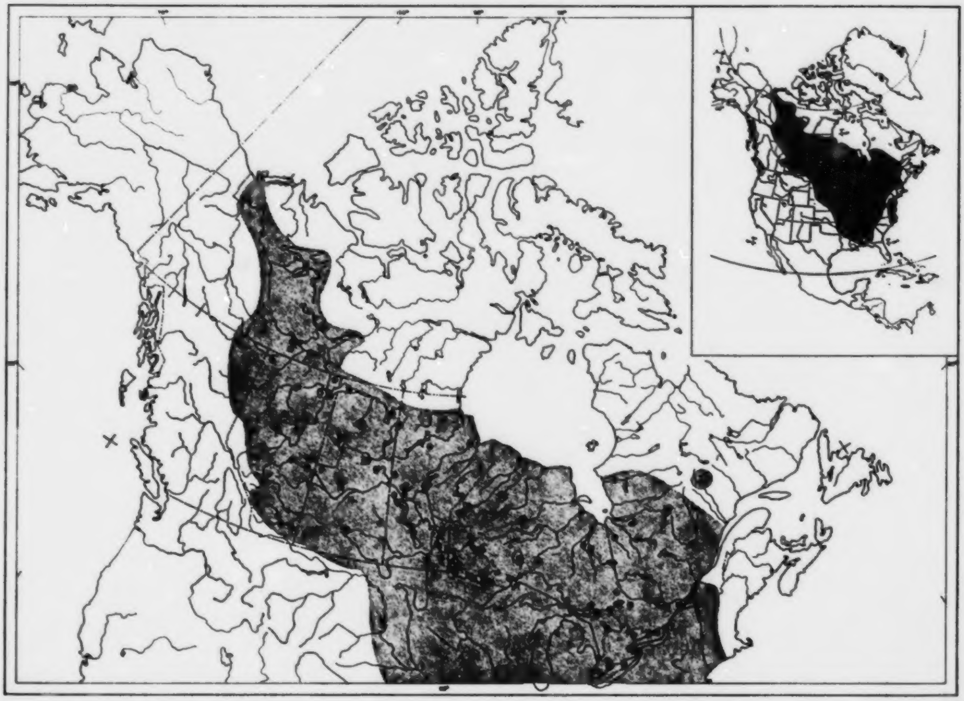
In most aspects other than colour and certain biological features, the two subspecies were difficult to separate. The eyes of the blue walleye were slightly larger, higher on the head, and consequently closer together (interorbital width less). Trautman (1957) showed a greater distance between angle of preopercle bone and branchiostegal rays, otherwise proportions and counts were very similar. The blue walleye had a different spawning time and place, a slower growth rate and smaller ultimate size, and different depth distribution.

The situation of establishing the distinction of the blue walleye was made doubly difficult by the high frequency of the supposed intergrades with the yellow walleye, the presence of grey-coloured mutants of the yellow walleye, and of supposed hybrids of both subspecies with the sauger. Stone (1948), who studied the taxonomy of these forms in lakes Erie and Ontario, concluded that the yellow and blue walleyes were separate species each with separate subspecies in each of the two lakes. This is interesting when we consider the 1970 evidence mentioned above of different genotypes.

The grey-blue walleyes seen regularly in Lake Nipissing, Ont., (and more rarely elsewhere) have long been considered by some to be blue walleyes. On the basis of characteristics available to us, this cannot be denied nor proven. They are largely undistinguishable from the blue-grey mutants of the yellow walleye seen elsewhere. One interesting fact is that they are seen there more often when there is a very successful year-class of yellow walleye dominating the fishery.

The common name of this species in Canada has long been a problem. Both the names pickerel and pike-perch allude to a supposed similarity between the head and teeth of this species and those of the northern pike. Since the name pickerel (a diminutive of *pick* or *pike*) was first applied to the smaller, new-world pikes *(Esox)*, the name walleye is more suitable and less confusing. It alludes to the smoky, silvery eye which is said to be similar to that of blinded or "walleyed" domestic animals. *See* Weed (1927) for an extensive list of common names of this species.

Distribution The walleye is limited to the fresh water (and rarely brackish water) of North America. It occurs from Quebec south to New Hampshire, southwest to Pennsylvania, southward west of the Appalachian Mountains to the Gulf coast in Alabama, northwest to eastern Oklahoma, northwest through the eastern half of the states from Nebraska to North Dakota, north to near the Arctic coast in the Mackenzie River, southeast across James Bay to Quebec. There is a residual, apparently native, stock along the central Atlantic seaboard (Pennsylvania to



North Carolina). It has been widely introduced elsewhere on the eastern seaboard and in virtually all the states to the west of its natural range.

In Canada it occurs generally in Quebec in tributaries of the St. Lawrence downstream at least to the Manicouagan River, north to rivers tributary to the east coast of upper James Bay, northwest from the Hudson Bay coast in Ontario to Athabasca, Great Slave and Great Bear lakes, north in the Mackenzie River to the delta, south through the Peace River drainage of northeastern British Columbia and south, east of the foothills, to southern Alberta (apparently much more sporadic and less abundant in northwest Alberta). It forms a dominant part of the fish fauna particularly in the boreal forest zone. Canadian stocks originate from a Mississippi and an Atlantic glacial refugium. It probably spread into northern Ontario, and Quebec via glacial lake Barlow–Ojibway and its outlets. It has been introduced in various places in Canada within its native range where barriers precluded its natural occurrence.

Contrary to a number of published range statements, it does not occur in Labrador.

The blue walleye occurred in Lake Erie, the lower Niagara River, and western Lake Ontario. It was reported as far east in Lake Ontario as the Bay of Quinte. Records of it in Long Lake, tributary to the Napanee River, and in other small inland lakes may have been based on the grey mutant of the yellow walleye. Its presence in Lake Nipissing is debatable (*see Systematic notes*).

Biology The biology of this species in Canada has been extensively studied. Information on Canadian populations was derived from Hart (1928), Kennedy (1949a), Rawson (1957), Payne (1964), Ellis and Giles (1965), Ryder (1968), and Regier et al.

(1969); and from publications on populations in the northern United States by Wolfert (1969) and Priegel (1970).

Spawning occurs in the spring or early summer (early April in southwestern Ontario, to end of June or later in far north) depending on latitude and water temperature. Northern populations do not spawn in some years when temperature is not favourable. Normally, spawning begins shortly after ice breaks up in a lake, at water temperatures of 44°–48° F (6.7°–8.9° C) but has been known to take place over a range of 42°–52° F (5.6°–11.1° C). Prespawning behaviour (courtship) may commence much earlier, when water temperature is 34° F (1.1° C). Males move to the spawning grounds first. Spawning grounds are the rocky areas in white water below impassable falls and dams in rivers, or boulder, to coarse-gravel shoals of lakes. Fish often move into tributary rivers immediately the rivers are ice free and while the lake is still ice covered. Spawning takes place at night, in groups of one larger female and one or two smaller males or two females and up to six males. Males are not territorial, and no nest is built. Prior to spawning there is much pursuit, pushing, circular swimming, and fin erection. Finally, the spawning group rushes upward into shallow water, stops, the females roll on their sides and eggs and sperm are released. Apparently most individual females deposit most of their eggs in one night of spawning. Egg diameter is 1.5–2.0 mm and eggs are sticky at first but apparently not so after water hardening. The eggs are broadcast and fall into crevices in the substrate (on mats of vegetation in flood-bench marshes in some areas of Wisconsin). Egg number has been given as high as 612,000 in females 31.5 inches (801 mm) in length, and it increases yearly at least to age 11. Eggs hatch in 12–18 days in temperatures prevalent on the spawning grounds. The yolk sac is absorbed rapidly (feeding takes place prior to disappearance of yolk) and by 10–15 days after hatching the young have dispersed into the upper levels of open water. Fish (1932), Norden (1961b), and Nelson (1968b) gave details of early development of young. Nelson also gave means of distinguishing between the young of walleye and sauger. Newly hatched fry are 6.0–8.6 mm in length and have 22–29 postanal myomeres. By the latter part of the summer, young-of-the-year move toward the bottom and are found in 20–30 feet (3.05–9.15 m) of water.

Growth is fairly rapid in the south but slower in the northern part of the range. In Lake Erie they may reach 3.5–8.0 inches (89–203 mm) by the end of the first growing season, but only 3–4 inches (76–102 mm) in the north. The following table gives the age–length and age–weight relations for various populations.

Payne (1964) gave the length–weight relation in Bay of Quinte, Lake Ontario, as Log W (pounds) = −3.690 × 3.271 Log L (fork length in inches). As can be seen, growth differential between Lake Ontario and Lac la Ronge can be as much as 4 inches (102 mm) at any age. There is a difference in the rate of growth of females over males. This occurs from age 7 onward in Saskatchewan and is approximately 6%. In the Moon River, Ont., females can be 2–4 inches (51–

		Age														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Bay of Quinte, L. Ontario (Payne 1964)	FL *inches*	8.4	12.7	15.8	18.3	20.4	21.9	23.0	24.2	25.0	25.6	26.3	26.2	26.5	27.0	27.8
	mm	213	323	401	465	518	556	584	615	635	650	668	665	673	686	706
	Wt (*lb*)	0.22	.83	1.70	2.75	3.92	4.95	5.81	6.86	7.63	8.25	9.01	9.00	9.24	9.82	10.80
L. Manitoba (Kennedy 1949a)	Avg FL *inches*	–	–	10.9	12.3	14.2	15.5	16.3	17.0	18.7	19.1	19.8	–	21.0	–	–
	mm	–	–	277	312	361	394	414	432	475	486	503	–	533	–	–
	Avg wt (*oz*)	–	–	9.8	14.0	20.7	25.1	30.7	34.4	47.4	52.6	57.5	–	71.6	–	–
Lac la Ronge, Sask. (Rawson 1957)	Avg FL *inches*	3.9	8.8	10.6	12.3	14.2	15.9	17.5	19.0	20.5	21.8	23.0	24.2	25.3	–	–
	mm	99	224	269	312	361	404	445	483	521	554	584	615	643	–	–
	Wt (*oz*)	–	2.9	4.5	9.0	16.3	–	26.3	36.0	–	48.0	–	61	79	–	–

102 mm) longer at any age. Growth rates for other Canadian populations were given by Adamstone (1922, Lake Erie) and Hart (1928, lakes Nipigon and Abitibi). Adamstone also contrasted with that of yellow walleye the age and growth of the blue walleye. The blue walleye at its maximum age (11) did not exceed 14.7 inches (375 mm) in length. Average weight at age 7 was 17 ounces.

Walleyes seen by anglers are usually 1–3 pounds in weight and 3 years of age. In Ontario, walleyes of 12–19 pounds win annual anglers contests but the largest Ontario walleye was 42 inches (106.7 cm) in fork length, 27 inches (686 mm) in girth, weighed 23 pounds 9 ounces, and was taken in spawning operations in Moon River, Georgian Bay. A 28-inch (711-mm) walleye is the largest known from Alberta. Trautman (1957) said that the largest Lake Erie specimen was 31 inches (787 mm) long, and weighed 11 pounds 14 ounces. The present angling record is a walleye taken in Old Hickory Lake, Tenn., in 1960, which was 41 inches (104.1 cm) long, 29 inches (737 mm) in girth, and weighed 25 pounds. The previous long standing record was a walleye of 22 pounds 4 ounces caught at Fort Erie, Ont., in 1943. The blue walleye rarely exceeded 12–14 inches (305–356mm) and ¼–1 pound.

Male yellow walleyes generally mature at 2–4 years of age, over 11 inches (279 mm) in length, and females at 14–17 inches (356–432 mm) or 3–6 years of age. Maximum age varies from 10–12 years in the south to a possible 20 years in the north. Gillnets in common use by commercial fishermen (4½ inch or 114 mm mesh) often take females before they have contributed to the population. Walleyes taken in the Georgian Bay commercial fishery are usually about 19 inches (483 mm) total length.

Walleyes are tolerant of a great range of environmental situations, but appear to reach greatest abundance in large, shallow, turbid lakes. Optimum transparency in a shallow lake, which will allow walleye to feed intermittently throughout the day, is in the order of 1–2 m Secchi disc. They also thrive in clear lakes but the special layer of the eye (*Tapetum lucidum, see* Ali and Anctil 1968) is extremely sensitive to bright daylight intensities, so feeding is restricted to twilight or dark periods. Large streams or rivers, providing they are deep or turbid enough to provide shelter in daylight, are suitable habitat. This species often uses sunken trees, boulder shoals, weed beds, or thicker layers of ice and snow as a shield from the sun. They may even remain in a depth, the temperature of which is above their usual selection, if there is better protection there. In clear lakes they often lie in contact with the bottom apparently "sleeping." In these lakes, they often feed from top to bottom at night. In more turbid water they are more active during the day, swimming slowly in schools close to the bottom. Walleyes are often associated with other species such as yellow perch, northern pike or muskellunge, and smallmouth bass. White suckers often orient themselves in walleye schools and behave as a part of it. The habitat does not change in winter except for an avoidance of strong currents. They are active all winter and are taken by ice fishermen. Usually fish of moderately shallow water (to 49 feet or 15 m) they were taken as deep as 69 feet (21.04 m) in August in Lac la Ronge whereas the blue walleye was usually found below 40 feet (12.2 m).

Movements involve a spring spawning run to shallow shoals or to tributary rivers, daily movements up and down in response to light intensity, and daily or seasonal movements in response to temperature or food availability. In Lac la Ronge, greatest net catches took place at depths where temperature ranged from 55.4°–64.4° F (13°–18° C) and in Wisconsin at 69.08° F (20.6° C). Their summer wanderings are usually limited to 3–5 miles, but tagged fish have been known to travel over 100 miles. *See* Magnin and Beaulieu (1968) for movements in the St. Lawrence River. There is evidence of homing to spawning grounds year after year in Michigan (Crowe 1962). Walleyes seem to remain in loose but discrete schools with separate spawning grounds and summer territories.

The food of the walleye shifts very quickly, with increase in size, from invertebrates to fishes. This is in part a reflection of their change in habitat from surface to bottom. During the first 6 weeks of life food consists mostly of copepods, Cladocera, and fish (*see* Priegel 1963b, for details). They are highly cannibalistic if small yellow perch or another forage fish are not more readily available. Some populations, even as adults, feed almost exclusively on emerging larval or adult mayflies or chironomids for part of the year.

The relative amounts of various species of fish taken apparently depend on availability. However, when present, yellow perch and freshwater drum seem very important. Species listed have been rainbow smelt, alewife, ciscoes, ninespine stickleback, white sucker, longnose sucker, yellow perch, lake whitefish, walleye, sauger, spottail shiner, darters, white perch, freshwater drum, trout-perch, emerald shiner, common shiner, silver chub, gizzard shad, rock bass, pumpkinseed, black crappie, smallmouth bass, brown bullhead, goldeye, mooneye, cottids, burbot, and various other unidentified minnows, as well as those regularly used as bait. It would seem safe to say they utilize any species of fish readily available to them. Other items such as crayfish, snails, frogs, mudpuppies, and small mammals are taken but only rarely, and usually when fishes and insects are scarce. Food in winter is not particularly different other than possibly in species composition.

Northern pike are probably the most important predators of the walleye over much of its range. The muskellunge also preys on walleye in more restricted areas. Northern pike may also be an important competitor as it is the only other major, shallow-water predator in the north. Adult perch, walleye, and sauger prey on the young as probably do a wide variety of predatory fishes. Many fish-eating birds and mammals, as well as lampreys, prey on walleyes regularly but are probably not important predators. Yellow perch, sauger, smallmouth bass, and lake whitefish compete with walleye for food. More important in controlling populations are water temperature, stream flow and wind at spawning time, and other species which spawn over the walleye eggs or roil up the silt. A major controlling factor is fry mortality (death + predation including cannibalism) which is up to 99% to the postlarval stage in some of the Finger Lakes in New York.

The walleye is host to a wide variety of parasites. Hoffman (1967) listed the following for the yellow walleye from the whole of its range: protozoans (3), trematodes (22), cestodes (10), nematodes (10), acanthocephalans (4), leeches (2), molluscs, crustaceans (7). Parasites from Canadian habitats were given in detail by Bangham and Hunter (1939) (both yellow and blue walleyes from Lake Erie), and Bangham (1955).

In certain areas of Saskatchewan and Alberta walleye are infected with the broad tapeworm *Diphyllobothrium latum*. This parasite regularly infects sleigh dogs fed raw fish, and human infection is known to have occurred. If fish are properly cooked this parasite will not infect man.

Lymphocystis, a virus disease, is very common on spawning walleye and appears as a white, tumorlike protuberance on the body. It apparently does not cause mortality in natural populations (Ryder 1961) and usually disappears when the water reaches summer temperatures. This species is also subject to black-spot and yellow grub and while these two parasites render the whole fish unsightly they can usually be removed by filleting and skinning, are harmless to man, and are killed when the fish are cooked.

The yellow walleye hybridizes in nature with the sauger (*see* Stroud 1948; and Nelson 1968b for details). In the past, intergrades between the yellow and blue walleye were common in Lake Erie.

Relation to man The walleye is probably the most economically valuable species in Canada's inland waters. It is a major commercial and sport fish in Ontario and the Prairie Provinces, and a sport fish in Quebec. An angler survey in Ontario showed that the walleye was the game species most often fished for and was the second most abundant in anglers' catches. It is an important species in both the summer sport fishery and for ice fishermen in the winter. The walleye is usually angled by still fishing with live minnows as bait or with artificial lures such as spinners, spoons, plugs, and jigs. Drifting and trolling seek out the schools of moving walleye. The two twilight periods of sunset and sunrise are the most productive. The walleye is not a spectacular fighter but a steady battler always boring for the bottom. The average walleye caught by angling is about 1½ pounds in weight.

Canadian commercial fisheries harvest several million pounds of walleye annually. Over the years 1919–1968 there was considerable fluctuation in catch but a peak of almost 21 million pounds in 1956 had a landed value of over 3.1 million dollars. The catch record also emphasizes the rapid decline since 1956. Lake Erie formerly produced about one-half of this catch but in recent years the fishery there has declined drastically due to overexploitation and deterioration of the environment (for details *see* Regier et al. 1969). In 1956, the Canadian and American walleye production from Lake Erie was 24 million pounds (Baldwin and Saalfeld 1962). As a result, the contribution of the Prairie Provinces to the total Canadian catch of 8.5 million pounds in 1968 was much higher than in previous years. The commercial fishery commonly employs gillnets and poundnets to harvest this species. Current fisheries are usually restricted by quota, minimum size, and minimum mesh-size regulations. The walleye has a firm, white to pinkish flesh, which is easily filleted and prepared. It is a prime species on the market, presently commanding as much as $1.25/pound depending on size, and type of processing and packaging. It is also highly regarded by anglers as a food fish.

Apparently competition between commercial and sport fisheries for this species has often led to heated controversy and to the necessity of a study of the walleye stocks in those areas. For extensive treatment of exploitation of such stocks, *see* Olson (1958), Ryder (1968), Regier et al. (1969), and numerous unpublished reports of various provincial governments. An extensive treatment of blue walleye fishery of Lake Erie was given by Parsons (1967).

Nomenclature

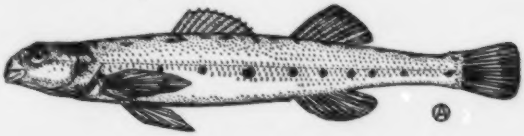
Perca vitrea — Mitchill 1818a: 247 (type locality Cayuga Lake, N.Y.)
Perca Fluviatilis — Pennant 1792: 298
Perca fluviatilis, var. ? L. — Richardson 1823: 725
Lucio-perca Americana (Cuvier) — Richardson 1836: 10
Lucioperca Canadensis — Forelle 1857: 280
Lucioperca grisea — Forelle 1857: 280
Lucioperca Americana — Forelle 1857: 280
Stizostedion vitreum (Mitchill) — Jordan and Evermann 1896–1900: 1021
Stizostedion glaucum — Hubbs 1926: 58 (type locality Lake Erie, off Ashtabula, Ohio)
Stizostedion vitreum vitreum (Mitchill) — Hubbs and Lagler 1941: 73
Stizostedion vitreum glaucum (Hubbs) — Hubbs and Lagler 1941: 73

Etymology *Stizostedion* — pungent throat; *vitreum* — glassy, alluding to the nature of the large, silvery eyes.

Common names Walleye, yellow walleye, wall-eye, pickerel, yellow pickerel, yellow pike, pike-perch, yellow pike perch, walleye pike, wall-eyed pike, wall-eyed pike-perch, wall-eyed pike perch, wall-eyed pickerel. French common name: *doré*.

EASTERN SAND DARTER

Ammocrypta pellucida (Putnam)



Description Body elongate, average total length about 2.5 inches (64 mm), not noticeably compressed laterally except posteriorly, body not deep, greatest depth less than head length, 8.6–11.9% of total length; flesh of body somewhat pellucid. Head moderate, its length 17.2–20.8% of total length, gill membranes joined at an acute angle and free from isthmus, opercle with a flattened, triangular spine; eye diameter 19.4–29.6% of head length; snout length usually greater than eye diameter, and often down curved, its length 26.5–32.7% of head length; premaxillaries non-protractile but separated from snout by shallow groove; mouth moderately large, maxillary not extending to anterior margin of eye; teeth small, fine, not enlarged. Branchiostegal rays 6,6. Fins: dorsals 2, first dorsal spiny, of 8–11 weak spines, second dorsal soft rayed, of 9–12 rays, usually 10 or 11, dorsals distinctly separated; caudal only slightly forked, nearly truncate, of 19 rays; anal with 1 thin weak spine and 8–10 (usually 9) soft rays; pelvics relatively well developed; pectorals relatively well developed. Scales ctenoid, 62–77 in a lateral series, weakly developed but better developed along midline of sides, scales above midline of sides with black margin posteriorly; lateral line usually complete or nearly so. Vertebrae 40–43.

Colour Overall colouration is light, the back is slightly yellowish, becoming silvery white on the lower part of sides and on ventral surface. There is a row of 10–14 small, rounded, green spots along the midline of each side, and 12–16 spots along midline of back, which become paired at bases of dorsal fins. Only adults exhibit the yellowish colouration while young fish tend to be white or silvery.

Distribution The eastern sand darter ranges from Lac St. Pierre in the upper St. Lawrence River, and the Lake Champlain drainage in Vermont, south to West Virginia and Kentucky; west through southwestern Ontario to southeastern Michigan.

In Canada it has been reported from Quebec in the lakelike expansions of the upper St. Lawrence River and their tributaries, such as Lac St. Pierre (Cuerrier et al. 1946, who reported it common in 1941), and Lake of Two Mountains and the Chateauguay River which flows into Lac St. Louis (Vladykov 1942). In Ontario, it was found occasionally in Lake Erie tributaries, in the Thames River of the Lake St. Clair drainage, and tributary streams of southern Lake Huron. It has not been reported from the north shore of Lake Ontario.

Except as noted above for Lac St. Pierre, it is not a common species and we know of no captures in Ontario streams for over 25 years, except for records from two Lake Erie tributaries in 1955.

Biology The eastern sand darter has received no attention in Canadian waters, beyond statements of its occurrence, and, hence, we have no direct knowledge of its biology.

The preferred habitat is said to be sand-bottomed areas in streams and rivers and sandy shoals in lakes. In such locations, the sand darter can bury itself with only its eyes exposed above the sand (Trautman 1957). The Chateauguay River specimens reported by Vladykov were caught over limestone terraces covered with a thin layer of mud with water temperature about 77° F (25° C) and *p*H of 8.6. The specimens taken in Lake of Two Mountains, Que., were caught over a sand–clay bottom, while the water temperature was 75.2° F (24° C) and *p*H 8.2.

During exploratory otter trawling in Lake Erie in 1957, by the United States Bureau of Commercial Fisheries, sand darters were caught in otter trawls at depths to 48 feet (14.6 m) in the eastern basin and from 18 to 42 feet (5.5–12.8 m) in the western basin.

From its place of concealment in the sand, the sand darter is said to dash out and capture passing prey. Midge larvae were found in the stomachs of darters captured in Ohio waters of Lake Erie (Turner 1921) and we presume that various entomostracans are among the major food items in Canadian waters.

Bangham and Hunter (1939) examined 15 sand darters from western Lake Erie and found 9 infected. The parasites identified were trematodes, *Neascus* sp., *Tetracotyle* sp., *Lebouria cooperi*, and nematodes *Camallanus oxycephalus* and *Agamonema* sp.

Relation to man This is an uncommon species in Canadian waters and is probably even less common now than formerly. It seems unlikely that it could long survive the environmental onslaught from highly industrialized areas, such as those around Montreal. Sand-bottom regions in streams and rivers, which is the preferred habitat, are much less available since such areas tend to become silted over, especially in the populated regions where this species occurred. Trautman (1957) noted that the preferred habitat was much reduced in Ohio and that sand darters were much less common than before 1945.

Nomenclature

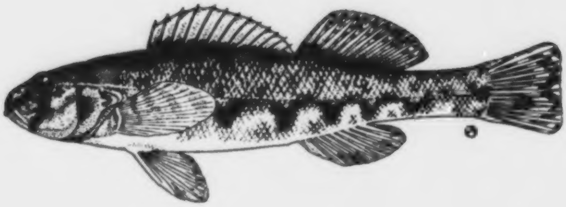
Pleurolepis pellucidus — Baird (*in* Putnam 1863: 5) (type locality — none)
Etheostoma pellucidum Baird — Putnam 1863: 5
Vigil pellucidus (Baird) — Jordan, Evermann, and Clark 1930: 288
Ammocrypta pellucida (Baird) — Dymond 1947: 25
Ammocrypta (Ammocrypta) pellucida (Agassiz) — Collette and Knapp 1966: 60
Ammocrypta pellucida (Putnam) — Bailey et al. 1970: 75

Etymology *Ammocrypta* — sand, concealed; *pellucida* — from *pellucidus*, meaning transparent.

Common names Eastern sand darter, sand darter. French common name: *dard de sable*.

GREENSIDE DARTER

Etheostoma blennioides Rafinesque



Description Body thick set and robust, average total length about 3 inches (76 mm), moderately deep bodied, especially adults, greatest body depth 15.1–17.9% of total length. Head moderate, triangular in cross section, its length 18.1–20.4% of total length, gill membranes broadly joined and free from isthmus, opercle with a small but sharp, conspicuous spine posteriorly; eye moderate, its diameter 23.8–28.2% of head length; snout bluntly rounded, projecting slightly beyond mouth opening, its length 23.9–30.8% of head length; premaxillaries separated from snout by a deep groove; mouth small and inferior; maxillary extending posteriorly to below nostril; posteriorly maxillary fused to preorbitals at sides, with only short groove near tip, upper lip sometimes with symphyseal knob; teeth in brushlike bands on upper and lower jaws, bands several teeth in width, outer teeth larger and more widely spaced, inner teeth small and close set, teeth on prevomer reduced, none on palatines. Branchiostegal rays 6,6(8), 6,7(1), 7,7(1). Fins: first dorsal, anal, pelvic and pectoral fins usually larger on males than females; dorsals 2, first dorsal spiny, spines strong, spines 12(7) or 13(13), second dorsal soft rayed, rays 12(4), 13(9), 14(7), fins close together, appearing to be conjoined in large males, second dorsal higher than spiny dorsal; caudal well developed, barred, weakly or shallowly forked; anal with 2 spines and 7(1), 8(11), or 9(8) soft rays, originating below origin of second dorsal; pelvics well developed, pointed on young, with rounded tips on adults; pectorals well developed, somewhat pointed, tips extending to beyond middle of spiny dorsal. Scales ctenoid, nape, cheeks, opercles and belly fully scaled; lateral line complete, 54–60 scales; swim bladder absent. Vertebrae 40(5), 41(3), or 42(1).

Colour Overall colouration olive-green or olive-brown dorsally, becoming pale green on sides, caudal, anal, and pelvic fins, and white or creamy white below. Young fish have 6 or 7 brownish saddle-shaped marks on the back which may be less obvious on the more heavily pigmented mature specimens. On the sides are 5–7 large olive-brown V-shaped marks which may be especially prominent on the latter half of the body of younger fish, and extend below the midline, but on larger fish these marks often tend to form a bandlike pattern. Two dark lines (on each side) extended downward from the eye, one forward toward the snout, and one downward and forward but passing posterior to the end of the maxillary. In life, the green colour with the peculiar lateral markings are distinctive. For a detailed account of spawning colouration *see* Fahy (1954).

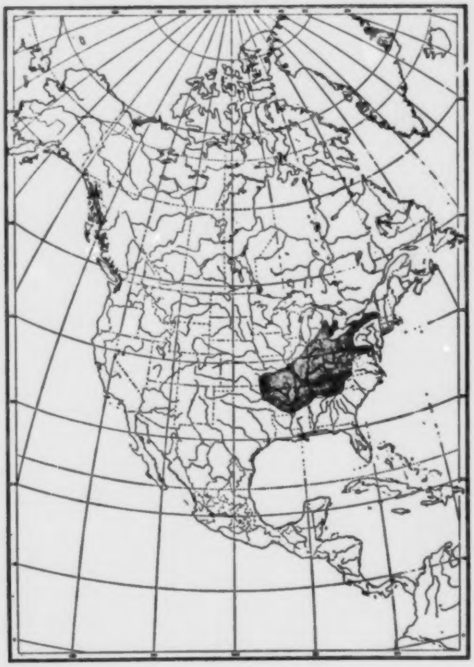
Systematic notes A thorough systematic study was presented by Miller (1968) in which four subspecies were recognized. The typical subspecies, *E. b. blennioides*, formerly considered to be the form occurring in the Great Lakes region (Hubbs and Lagler 1958) was redefined and considered to occur in Ohio, upper Genesee and Potomac rivers. The Great Lakes population (including the Thames River and Lake St. Clair populations of Ontario) were assigned to a new subspecies, *E. b. pholidotum*, composed of two races, a Wabash River Great Lakes race and a Missouri race, the total range of the subspecies extending from eastern New York State, the lower Great Lakes southwestward to eastern Kansas. *See* Miller (1968) for further details.

Distribution The greenside darter ranges in east-central North America, in streams of lower Great Lakes, Potomac, and Mississippi drainage systems from eastern New York on the east to Kansas, and Oklahoma on the west, south to northern Alabama and Arkansas.

In Canada it occurs only in the Lake St. Clair drainage of southwestern Ontario and has been recorded from Lake St. Clair and the Thames and Avon River systems.

Biology The biology of the greenside darter has received considerable attention but no studies have been published on Canadian populations. In view of the extremely limited Canadian distribution, detailed treatment of the extensive literature seems unwarranted here. Therefore, the following is a brief account of the biology of this species. For additional information, *see* Turner (1921), Fahy (1954), Winn (1958a, b) or Miller (1968).

According to Fahy, spawning was initiated in Salmon Creek, Lake Ontario drainage of New York, when water temperature reached 51° F (10.6° C). This temperature is critical and spawning ceased if temperatures dropped below 51° F. Given favourable conditions, the spawning season extended from mid-April to mid-June. Actually spawning occurred in early morning and throughout the day (Winn 1958b) although Fahy suggested that the species spawned at night. The reproductive behaviour of many darters is rather unusual and the greenside darter is no exception. The male usually selects a territory but the female selects the spawning site, and, if necessary, will stimulate the male by swimming and nudging actions. The female assumes a position on an algal-covered boulder or other object, usually at a distinct angle, which apparently also stimulates the male who then assumes a position on top of her. Filamentous algae, especially *Cladophora*, is commonly a site for egg deposition. *See* Winn (1958a, b) for a complete description of spawning behaviour of this and many other darter species, and *also* Fahy (1954).



The number of eggs laid varied from 466–1832, depending upon size of female; ripe eggs averaged 1.8 mm in diameter and were adhesive when deposited. Hatching occurred in 18–20 days at temperatures of 54.4°–59.0° F (13°–15° C). The development of eggs and larvae were described in great detail and illustrated by Fahy.

Fahy found that reliable age determinations could be made from scales. Males grew faster and attained a greater size than females, but both sexes attained over 60% of their growth in the first growing season. Three years was a typical life span but a few individuals survived a fourth or even a fifth growing season.

Studies in Ohio waters of Lake Erie by Turner (1921) indicated that the young fed on midge larvae, cladocerans, and copepods, in that order. Midge larvae remain the most important food at all ages, especially in Lake Erie. The diet was more varied in Ohio streams and although midge larvae were still important, mayfly larvae and, to a lesser extent, caddisfly larvae, were significant supplementary foods. In Lake Ontario tributaries of New York State, Fahy found insect larvae to be important in the diet, especially blackfly, midge, and caddisfly larvae.

Bangham and Hunter (1939) examined 10 specimens from United States waters of western Lake Erie and found 3 infected. Parasites identified were trematodes *Allocreadium* sp. and *Tetracotyle* sp., and nematodes *Camallanus oxycephalus*. Hoffman (1967) listed only one parasite, the trematode *Phyllodistomum etheostomae* from the greenside darter.

Relation to man The greenside darter is of no known direct importance to man but indirectly it could be of considerable interest as an experimental or laboratory animal, particularly in behavioural studies. Unfortunately, the Ontario distribution is limited and the stocks could be depleted if overfished.

Nomenclature

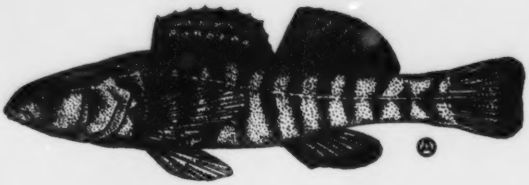
Etheostoma blennioides — Rafinesque 1819: 419 (type locality Ohio River)
Diplesion blennioides (Rafinesque) — Jordan and Evermann 1896–1900: 1053

Etymology *Etheostoma* — from *etheo* — to strain, *stoma* — mouth; *blennioides* — *Blennius* — blenny; likeness.

Common names Greenside darter, green-sided darter. French common name: *dard vert.*

RAINBOW DARTER

Etheostoma caeruleum Storer



Description Body short, average length about 2 inches (51 mm) robust and rather deep, greatest body depth 17–20% of total length, noticeably compressed laterally. Head triangular, its length 19.1–23.9% of total length, gill membranes joined at an acute angle and free from isthmus, opercle with small but sharp, conspicuous spine posteriorly; eye moderate, its diameter 20.5–26.2% of head length; snout rather pointed and projecting beyond lower jaw; premaxillaries bound to snout by a frenum, i.e., no groove across snout; mouth of moderate size, lower jaw overhung by snout, maxillary extending posteriorly to below anterior margin of orbit; teeth in brush-like bands in upper and lower jaws, bands several teeth in width, outer teeth larger and more widely spaced, inner teeth small and closely set. Branchiostegal rays 6,6(9), 7,6(2). Fins: dorsals 2, first dorsal spiny, spines strong, usually 10(16), sometimes 9(3) or 11(2), second dorsal soft rayed and distinctly higher than spiny dorsal, rays usually 13(15), sometimes 12(5), or 14(1), fins close together but distinctly separated; caudal well developed, speckled on females, truncate; anal with 2 spines and 6(9) or 7(12) rays, originating below origin of second dorsal, smaller than second dorsal in females, about equal to second dorsal in males; pelvics well developed, pointed; pectorals well developed, larger than pelvics, somewhat pointed, rays usually 13, sometimes 12 or 14. Scales ctenoid, cheeks appear scaleless but some scales apparent on cleared and stained specimens, opercles scaled; lateral line usually incomplete, pored scales 27–34, scales in lateral series 42–45. Vertebrae usually 35(8), sometimes 34(1).

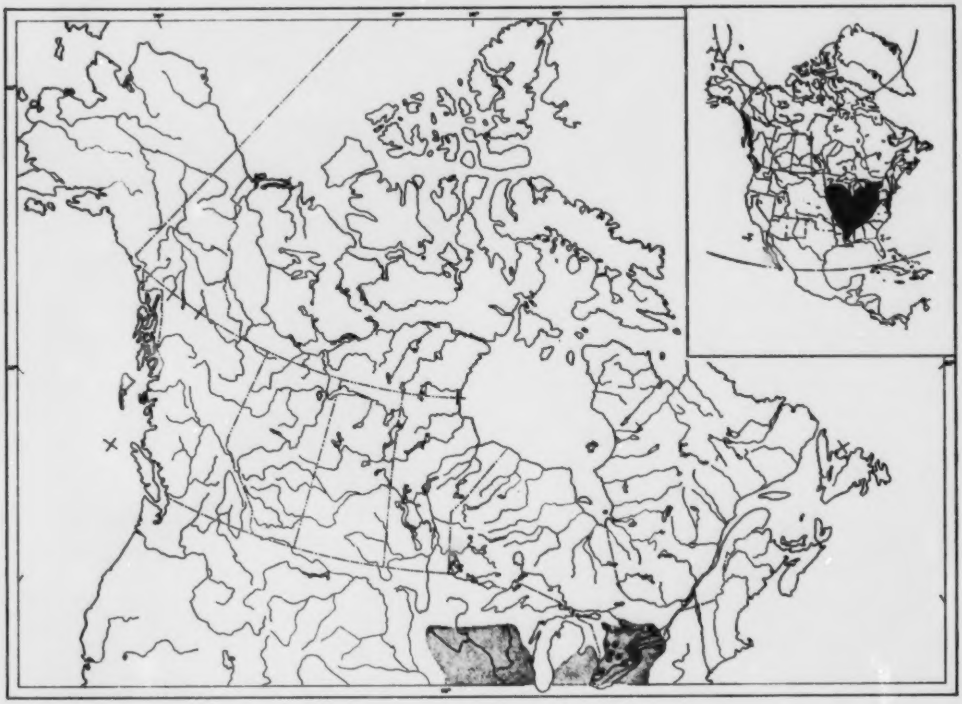
Colour The male rainbow darter, in breeding dress, is probably the most colourful of all our native fishes, but, because of its small size and limited distribution, it is infrequently seen and not well known.

Overall, the breeding male is a colourful array of brilliant blues and greens on head and breast and on the bars on flanks, with interspaces of yellow or orange; the two dorsal fins and the anal fin, especially of males, display the same tones of green, yellow, and orange but each has a narrow outer margin of brilliant blue-green.

There are 6–10 saddle marks or blotches on the back, and 9–14 vertical bars or bands on the sides; posterior to the anus the vertical bars are most pronounced and usually encircle the body but anteriorly they are weaker and often ill-defined.

The males are much more colourful and have more conspicuous vertical bars than the females. Young fish may lack the colour but display the vertical bars, although young males exhibit partial colouration. *See* colour illustration facing p. 730.

Systematic notes The rainbow darter displays little morphometric or meristic variation throughout most of its range, but the southwestern populations exhibit more variation than any others. An intensive



systematic study of this darter was completed by Knapp (1964) who proposed three subspecies, *E. c. caeruleum*, *E. c. oreium*, and *E. c. notiale*. Ours is the typical subspecies, *E. c. caeruleum*, which is wide ranging while the other two have more restricted distributions in south-central United States.

Distribution The rainbow darter ranges through the Great Lakes drainage area (except Lake Superior) west from New York State to Minnesota; south of the Great Lakes states in the Mississippi and Ohio River systems to Alabama, Mississippi and Arkansas.

In Canada, the species is found only in southern Ontario in streams entering lakes Ontario, Erie, St. Clair, and Huron.

Biology Spawning occurs in spring in coarse gravel, fine gravel, or rubble riffles in streams. In Michigan waters, males move to the riffles in late March and establish relatively small (1 foot wide by 2 feet long), shifting territories. The males attain a larger size than females and engage in much sham fighting, displaying their brilliant colours with fins erect. When ready to spawn, the female enters the riffles with its attendant ripe and rival males and after a period of courtship, wiggles, head first, into the gravel. The male moves over the female, his caudal region depressed beside hers. They vibrate briefly, the female extrudes a few eggs (less than 10), the male exudes milt, fertilizing the eggs, the female moves out of the gravel, leaving the eggs buried. The same female may move forward on the riffle, repeating the performance a few or several times, before returning to the pool below the riffles. Spawning continues until the total egg complement, averaging about 800 eggs, is deposited. Ripe eggs average 1.5–1.8 mm in diameter and hatch in 10–12 days at temperatures of 62.2°–65.3° F (17.0°–18.5° C). The development and pigmentation pattern of the larvae was described and illustrated by Fish (1932).

For additional information on reproduction, *see* Winn (1958a, b) the source for much of the above. Winn (1958b) also noted that Reeves (1907) inadvertently included two species in the otherwise detailed account of the breeding behaviour of the rainbow darter.

Age can be determined by scale examination but detailed studies of growth are not available especially for Canadian populations. In Ohio, young rainbow darters attained lengths of about 1.1–1.8 inches (28–46 mm) by October of their first year. The largest Canadian specimen examined by us was one 2.5 inches (65 mm) total length, from the Saugeen River, Ont.

Rainbow darters are inhabitants of gravel or rubble-bottomed clear water streams in glaciated regions, particularly in streams of moderate to large size. Shallow water or rocky or gravelly riffles are essential for breeding. Given suitable conditions rainbow darters may be extremely abundant.

Midge (chironomid) and mayfly larvae were of primary importance in the diet of rainbow darters of all sizes but larger insect larvae such as caddisflies, as well as snails, and small crayfish were eaten by large adults in Ohio streams studied by Turner (1921). They also eat eggs of stream-spawning minnows and lampreys (Winn 1958b).

We have no information on the utilization of rainbow darters by stream-dwelling trout and other predaceous fishes but assume that, when available, they are utilized by larger trout as food.

Only one rainbow darter was examined during the Lake Erie survey by Bangham and Hunter (1939) and it was free of parasites.

Hoffman (1967), however, listed the following parasites from this species: trematodes (5), cestodes (1), nematodes (1), acanthocephalans (1), molluscs (1), and crustaceans (1).

Relation to man The rainbow darter is an exquisitely beautiful inhabitant of clean, gravelly Ontario streams and is of value for this reason alone, although we know of no direct economic importance. Perhaps it is of greatest value to man as an indicator of pollution for it is extremely sensitive to chemical pollution and silting. Its native range is documented, and it can be readily observed by competent field biologists. It is perhaps of more than passing interest that rainbow darters were noted to feed on the eggs found in brook lamprey nests in Michigan (Winn 1958b).

In our experience, it does not adapt easily to the home aquarium, although it can be retained indefinitely in a well-equipped laboratory or hatchery-type facility.

Nomenclature

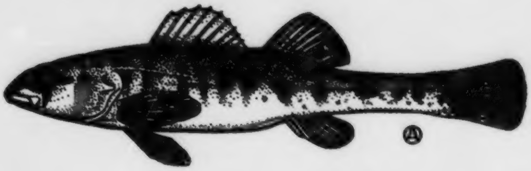
Etheostoma caerulea — Storer 1845: 47 (type locality Fox River, Ill.)
Etheostoma coerulea — Storer 1846: 272
Etheostoma coeruleum Storer — Jordan and Evermann 1896–1900: 1088
— Halkett 1913: 85
Oligocephalus caeruleus (Storer) — Jordan, Evermann, and Clark 1930: 291
Poecilichthys coeruleus (Storer) — Toner 1937: 17
Poecilichthys caeruleus (Storer) — Radforth 1944: 61
Etheostoma caeruleum Storer — Hubbs and Lagler 1958: 109

Etymology *Etheostoma* — from *etheo* — to strain, *stoma* — mouth; *caeruleum* — from *caeruleus*, meaning blue.

Common names Rainbow darter, rainbow fish, blue darter, banded darter. French common name: *dard arc-en-ciel.*

IOWA DARTER

Etheostoma exile (Girard)



Description Body slender, short, average length about 2 inches (51 mm), somewhat compressed laterally but not markedly deep bodied, greatest body depth 12.7–16.0% of total length. Head low, elongate, its length 19.8–22.8% of total length, gill membranes joined at an acute angle and barely free from isthmus, opercle with a small, sharp and rather inconspicuous spine posteriorly; eye rather large, its diameter 23.8–29.3% of head length; snout rounded, slightly projecting beyond lower jaw, its length 20.3–26.4% of head length; premaxillaries bound to snout by a frenum, i.e., no groove across snout; mouth moderate, lower jaw barely included in upper, maxillary extending posteriorly to below anterior margin of pupil; teeth in brush-like bands in upper and lower jaws, bands several teeth wide, outer teeth larger and more widely spaced, inner teeth small and closely set. Branchiostegal rays 5,5(1), 6,5(1), 6,6(15), 7,7(3), 7,6(1). Fins: dorsals 2, first dorsal spiny, spines strong, spines usually 8–10 (rarely 7), second dorsal soft rayed, slightly higher than spiny dorsal, rays usually 11(20), sometimes 10(17), or 12(4), fins distinctly separated by 2 or 3 scale lengths (*see Systematic notes*); caudal well developed, distinctly speckled, truncate; anal with 1(7) or 2(32) spines, and 7(18) or 8(22), rarely 6(1), rays, smaller than second dorsal; pelvics rather small, somewhat pointed; pectorals well developed, distinctly rounded, rays 12–14. Scales ctenoid, cheeks and opercles lightly scaled; lateral line incomplete, terminating under second dorsal, 18–28 pored scales, 45–60 scales in lateral series. Vertebrae usually 36(7) or 37(10), occasionally 35(2) or 38(2).

Colour Overall colouration is dark brown or olive-brown on back and sides, becoming yellowish or creamy white below. There is a distinct vertical, suborbital bar. On the back are about 8 narrow, saddle-shaped, darker marks, while midlaterally, on the sides, are 10–14 (usually 11) short, dark, vertical bars that do not extend to dorsal or ventral surfaces. The pelvic and anal fins are usually only lightly speckled with pigment, the pectorals somewhat more so, but the dorsal and caudal fins are distinctly pigmented; the caudal fin marking takes the form of a number of regular spots on the fin rays producing a series of arc-like lines.

The breeding male is exceedingly colourful; the first dorsal fin is blue at base, then a transparent section blending with an orange or reddish band and finally edged with a deep blue (or blue-green) band. The bands on the sides take on an intense blue or blue-green colour, the intervening spaces an orange, orange-red, or yellow, with yellow on the ventral surface; the pectoral and anal fins yellow-orange or orange-red. *See* Dymond (1926) for additional colour notations.

Systematic notes The Iowa darter has long been known to exhibit wide variability throughout its extensive range, and because of this variability, has acquired many synonyms; *see* Hubbs (1926) for a review of some of these. Many other authors, including Richardson (1938) and Carlander (1941), have remarked on the variability of the species but Gosline (1947) provided the most intensive in-depth study of meristic variation of the species. *See also* Bensley (1915) and Dymond (1926) for descriptive details of specimens from Georgian Bay and Lake Nipigon, Ont., respectively.

Although the sample sizes are small, there are indications of interesting trends in meristics when comparing Ontario and Saskatchewan specimens as the following table shows. In addition, branchiostegal rays range from 5,5 to 6,6 in Saskatchewan and from 6,6 to 7,7 in Ontario specimens.

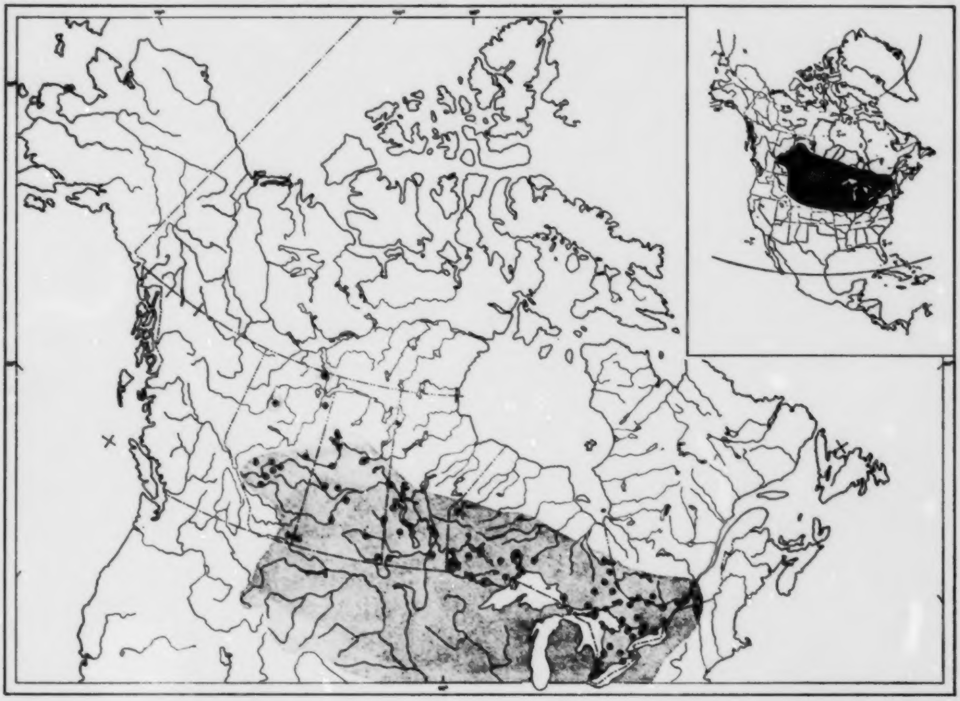
Distribution The Iowa darter occurs from southern Quebec and the Allegheny drainage of New York, west through the Great Lakes drainage area, and adjoining states to Iowa, Nebraska, Colorado, Montana, and Alberta.

In Canada it occurs from southern Quebec in the upper St. Lawrence–Lake Champlain area and Lac St. Pierre, west throughout the Great Lakes drainage of Ontario to Lake of the Woods, and north to the James Bay watershed; throughout southern Manitoba, extending north to the Saskatchewan River near The Pas; in central and southern Saskatchewan in the Churchill River and North and South Saskatchewan River systems, the Qu'Appelle valley, Antler River, and Cypress Hills area; in southern Alberta recorded from the Cypress Hills region, Square Lake (east of Lac la Biche), and from the North Saskatchewan River, Red Deer River, and recorded in 1966 from Pine Lake, northern Alberta, about 40 miles south of Fort Smith, N.W.T. (D. E. McAllister personal communication). This isolated record is the northernmost limit of range. This species has the widest Canadian distribution of any darter.

Biology Spawning occurs in southern Michigan during April and May but considerable variation in time of spawning may occur between adjacent localities. There is little published information on the time of spawning in Canadian waters but it is presumably later than in southern Michigan. For example, Dymond (1926) noted that females with nearly ripe eggs were taken in Lake Nipigon on June 19, 1924, and Bensley (1915) stated that the breeding season included the latter part of May and June, in the Georgian Bay region of Lake Huron.

In southern Michigan, Winn (1958b) observed that adults moved from the deeper waters of Lake Whitmore to the shallows near shore. Here the males established territories. The females moved in from deeper water to spawn in a male's territory, and moved from territory to territory, mating several times with different males before moving offshore into deeper water. Spawning took place, in this case, on fibrous-root material under undercut banks, usually in shallow water less than 15 inches deep. Characteristically, the species spawns in shallow water of lakes, or pondlike expansions in rivers, on bottom organic debris or on fibrous roots in mudbanks. Winn (1958b) noted that only rarely did spawning occur on sand or on organic material on sand, and this only when undercut banks were not available. The actual spawning act, under natural conditions, was not observed by Winn because of the location under banks, but from laboratory observations it is known that the male moves over the female, his caudal region depressed beside hers, in the manner characteristic of most darters. The eggs are deposited in groups of 3–7, according to Winn, and average 1.1 mm in diameter. A total

	Dorsal				Anal					Vertebrae			
	Spines				Spines		Soft rays						
	7	8	9	10	1	2	6	7	8	35	36	37	38
Ontario		4	10	8	1	21		12	10		3	8	1
Saskatchewan	1	11	9	1	6	13	1	6	12	2	4	2	1



of 550–2048 eggs may be laid, the larger and older females laying the greater number. Hatching occurred in 9–10 days at temperatures of 55.4°–60.8° F (13°–16° C). A description and illustration of a 19.5 mm stage larva from Lake Erie was presented by Fish (1932). Little information is available on rate of growth but Winn (1958a) indicated that adults may live at least 3 years. Adults normally attain lengths of 2.0–2.3 inches (51–58 mm) in Canadian waters. Females attain a larger size than males. The largest specimen examined by us was 2.7 inches (68 mm) total length, from Quetico Provincial Park, Ont.

Iowa darters are inhabitants of clear, standing, or slowly moving waters of lakes or rivers, having rooted aquatic vegetation, and a bottom of organic debris, sand, peat, or a composite of these. It is a glacial relict species that can apparently withstand cooler waters than other darters since it ranges farthest north. Like most darters it is intolerant of turbid, muddy waters of low visibility, which destroy its food supply. Trautman (1957) noted that it has become greatly reduced in numbers in many parts of Ohio since 1930.

Midge larvae, mayfly larvae, and amphipods were of primary importance in the diet of adult and juvenile Iowa darters, but small crustaceans, such as copepods and cladocerans, were the principal food of the young (Turner 1921). Additional items eaten by large adults include snails and corixid nymphs.

We have no details of predation on Iowa darters by other fishes, but, since it is an inhabitant of lakes, there is little doubt that it contributes to the diet of piscivorous fishes. During survey work in eastern Ontario watersheds, Toner (1943) remarked on the absence of northern pike in those areas where *E. exile* were caught, and suggested that it fell prey to northern pike.

Bangham and Hunter (1939) examined 7 specimens from the west end of Lake Erie and reported 5 parasitized. Parasites identified were the trematodes *Allocreadium* sp., and *Tetracotyle* sp., the larval or immature form of the cestode *Bothriocephalus cuspidatus*, nematodes *Agamonema* sp., and the acanthocephalan *Leptorhynchoides thecatus*. All 5 specimens from Lake Huron and Manitoulin Island examined by Bangham (1955) were infected. Two darters were from Lily Lake and 3 from South Bay, yet the parasites infecting the fish from the two areas were different. Parasites included 3 species of trematodes, 2 of cestodes, 2 of nematodes, and a leech, *Illinobdella* sp.

Hoffman (1967) listed protozoans (3), trematodes (6), cestodes (2), nematodes (5), acanthocephalans (4), molluscs (1), and leeches (1), from Iowa darters in North American waters.

Relation to man There is no direct information on the role of the Iowa darter in the economy of our waters. But, since it is widely distributed in Canada, and feeds mainly upon benthic organisms in lakes, there can be little doubt of its importance in the aquatic ecosystem.

Nomenclature

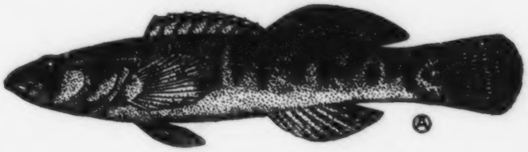
Boleichthys exilis	— Girard 1860: 103 (type locality Little Muddy River, trib. Upper Missouri)
Etheostoma iowae Jordan and Meek	— Eigenmann and Eigenmann 1892: 962
Etheostoma quappella E. and E.	— Eigenmann and Eigenmann 1892: 963
Boleichthys fusiformis (Girard)	— Dymond 1922: 71
Poecilichthys exilis Girard	— Hubbs 1926:64
Etheostoma boreale Boulenger	— Hubbs 1926: 65
Oligocephalus iowae (Jordan and Meek)	— Jordan, Evermann, and Clark 1930: 291
Etheostoma exile (Girard)	— Bailey 1951: 232
Poecilichthys borealis Jordan	— Collette and Knapp 1966: 61

Etymology *Etheostoma* — from *etheo* — to strain, *stoma* — mouth; *exile* — from *exilis*, meaning slim or slender.

Common names Iowa darter, yellowbelly, weed darter. French common names: *dard à ventre jaune, dard d'herbe.*

FANTAIL DARTER

Etheostoma flabellare Rafinesque



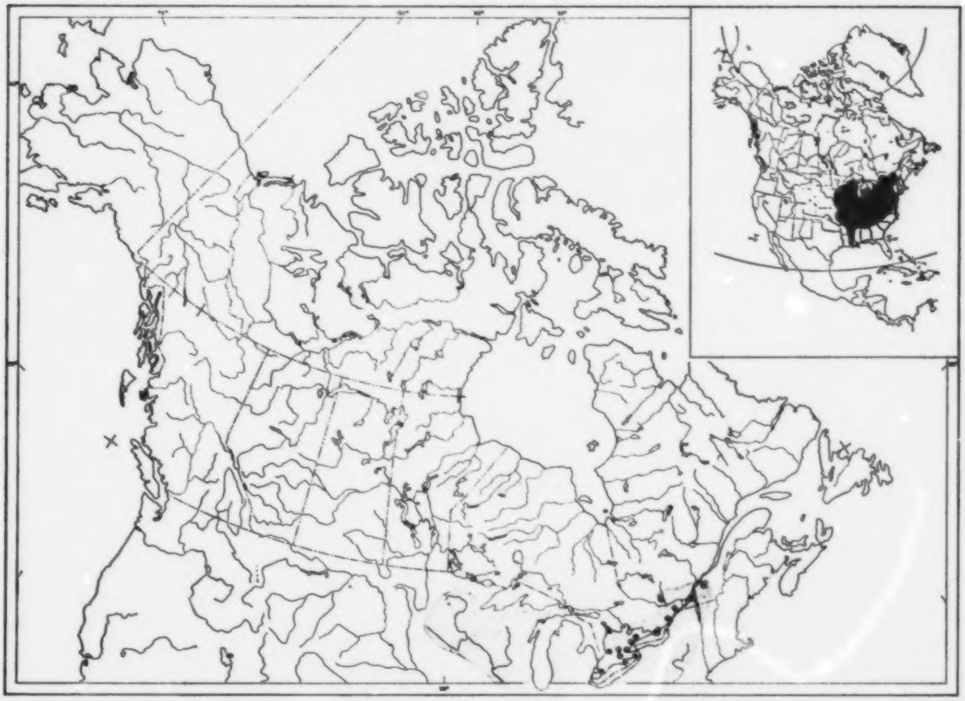
Description Body elongate, robust, average length about 2 inches (51 mm), somewhat tube-like in appearance due to deep caudal peduncle, no marked variation in body depth, especially in subadults, greatest body depth 11.6–16.8% of total length. Head low, elongate, pointed, its length 21.1–24.0% of total length, gill membranes broadly joined and free from isthmus, opercle with small inconspicuous spine posteriorly; eye moderate, its diameter 19.5–24.4% of head length; snout straight, not rounded, its length 21.9–28.3% of head length, not projecting beyond lower jaw; premaxillaries bound to snout by a frenum, i.e., no groove across snout; mouth large, upper and lower jaws about equal, maxillary extending posteriorly to below anterior margin of pupil; teeth in narrow, brushlike bands on upper and lower jaws, outer anterior teeth in both jaws enlarged, slim, pointed, remaining teeth smaller. Branchiostegal rays 6,6(13). Fins: dorsals 2, first dorsal spiny, spines strong, short, usually 7(15) or 8(7), sometimes 6(1), each spine tipped with fleshy knob on spawning males only, second dorsal soft rayed, higher than spiny dorsal, rays usually 13(12), 14(7), or 12(4), fins close together but distinctly separated; caudal well developed, distinctly barred, rounded, not truncate; anal with 2 spines and 7(3), 8(18), or 9(2) soft rays, smaller than second dorsal; pelvics small, narrow, shorter than pectorals; pectorals rounded, fanlike, rays 12 or 13. Scales ctenoid, cheeks and opercles naked; lateral line incomplete, 27–35 pored scales, 47–51 scales in lateral series; swim bladder absent. Vertebrae 32(2), 33(8), or 34(3).

Colour Overall colouration is brown or olive-brown with 9–12 short, dark, vertical bars on sides that are often vague or ill-defined. Breeding males may also exhibit lengthwise rows of broken or unbroken lines. Colour of ventral surface creamy white, yellowish, or dusky. The males lack the colourful spawning dress so typical of many darters, but become darker and have the tips of the dorsal spines topped by yellow-orange or orange coloured fleshy knobs. The fins are weakly or not pigmented, except for the second dorsal which is speckled and the caudal which is conspicuously barred with about 6 dark, narrow bands. Spawning males may also have weakly spotted pectoral and anal fins.

Systematic notes Two subspecies are described, the typical subspecies, *E. flabellare flabellare*, the barred fantail, and *E. f. lineolatum*, the striped fantail. The form occurring in our area is *E. f. flabellare*, which shows little morphological variation within the region.

Distribution The fantail darter occurs from southern Quebec and eastern New York, west through the southern Great Lakes drainage, including Lake Michigan, to Iowa and Kansas, south to North Carolina, Kentucky, Tennessee, and in the Mississippi River, to Louisiana and Mississippi.

In Canada, it is known from the tributaries of Lake St. Francis of the upper St. Lawrence River system in southern Quebec, west in the



lower Ottawa River, to the tributary streams of lakes Ontario, Erie, and southern Lake Huron, northward to Grey County at the base of the Bruce Peninsula.

Biology In the spring, fantail darters move from swift waters of riffles into slower-moving waters, in preparation for spawning. A male will set up a territory under a rock, and the females move into the territories to spawn. In the latitude of Rochester, N.Y., Lake (1936) reported that movement into the spawning area commenced in late March and extended into April, and that egg-laying and incubation extended from April 26 to June 22. No observations are available on dates of spawning in Canadian waters, and most of the following information was derived from Lake and from Winn (1958a, b).

The method of spawning and the spawning site are unusual. The undersurface of the rock is separated from the bottom gravel by a distance about equal to the body depth of the male with dorsal spines in an erect position. This distance is critical and is of the order of 15–25 mm. The male moves around under the rock, dorsal spines erect, and the fleshy bulbous tips on the spines clean off the surface of the rock in preparation for the eggs. When a female moves into the territory, she is met by a male who leads her under the rock, performing a series of movements involving circles and figure eights. Eventually after a courtship that may involve leaving the shelter of the rock and re-entering, the female turns upside down and with the male right side up, and head to tail, they move in circles and figure eights. After a time, the female presses her vent against the surface of the rock, vibrates slightly, and extrudes a single, adhesive egg which sticks to the rock. At this moment the male turns upside down, fertilizes the egg, body vibrating briefly, and then immediately turns right side up again. The female remains upside down and the egg deposition and fertilization continue until about 34 eggs, on average, are deposited. While under the rock, movement is achieved by the use of the pectoral and caudal fins. When a female has released her complement of eggs, she either leaves or is driven out of the nest, and the process repeated with another female. The male guards the nest and moves around under the eggs, brushing them with the bulbous tips of the dorsal spines and the soft dorsal fin. Lake indicated that the eggs quickly became infected if left untended and Cross (1967) suggested that mucus from the male may have bactericidal and fungicidal effects since males seem especially slimy during spawning.

Several females may deposit their eggs in the nest. Lake, by actual count, found the number of eggs in the nests to vary from 8 or ten to 562. Winn (1958a) counted 120–467 eggs per female, the greater number in the larger fish. A large female may spawn up to five times in a single season. The eggs are large and average 2.3 mm in diameter and hatch in about 21 days at a temperature of about 70° F (21.1° C). Descriptions of developmental stages were provided by Fish (1932) and Lake (1936).

Age and growth were reported for Iowa waters by Karr (1964), who used scales to determine ages. Males attained a larger size and lived a year longer (to 4 years) than females (3 years). Karr's samples ranged in total length to 2.7 inches (70 mm) and we have examined Canadian specimens to 2.5 inches (65 mm) total length.

Fantail darters require small, shallow-water, gravel and boulder-bottomed streams, usually less than 18 inches deep, for spawning, and deeper, downstream waters for overwintering. Slow to moderate currents seem to be preferred. It seems to be less sensitive to moderate turbidity and silting than the rainbow darter.

Studies by Turner (1921) in Ohio suggested that the fantail darter limited its diet primarily to mayfly larvae. Turner found surprising the size of the food items ingested, for sometimes an individual larvae eaten was almost as long as the fish. The size of the food items increased with the size of the fish, and beetle larvae, caddisfly larvae, and corixids were also taken. Amphipods were of some importance in Lake Erie but were not eaten by stream-dwelling fish.

Bangham and Hunter (1939) examined 18 specimens from the eastern end of Lake Erie, and found 10 infected. Of the 5 examined, from the west end of the lake, only one contained parasites. All were trematodes, *Clinostomum marginatum*, *Neascus* sp., and *Tetracotyle communis*.

Hoffman (1967) listed trematodes (9), cestode (1), nematodes (3), acanthocephalans (3) and molluscs (1).

Relation to man No direct economic significance is apparent but the species offers unique opportunities for behavioural study, although these are limited because of the restricted Canadian distribution of the species.

Nomenclature

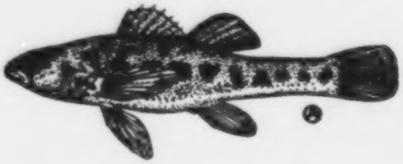
Etheostoma flabellaris — Rafinesque 1819: 419 (type locality Ohio River)
Etheostoma flabellare Rafinesque — Jordan and Evermann 1896–1900: 1097
Catonotus flabellaris Rafinesque — Hubbs 1926: 68
Poecilichthys flabellaris — Speirs 1951: 2

Etymology *Etheostoma* — from *etheo* — to strain, *stoma* — mouth; *flabellare* — *flabellaris*, meaning like a fan, from the form of the tail.

Common names Fantail darter. French common name: *dard barré*.

LEAST DARTER

Etheostoma microperca Jordan and Gilbert

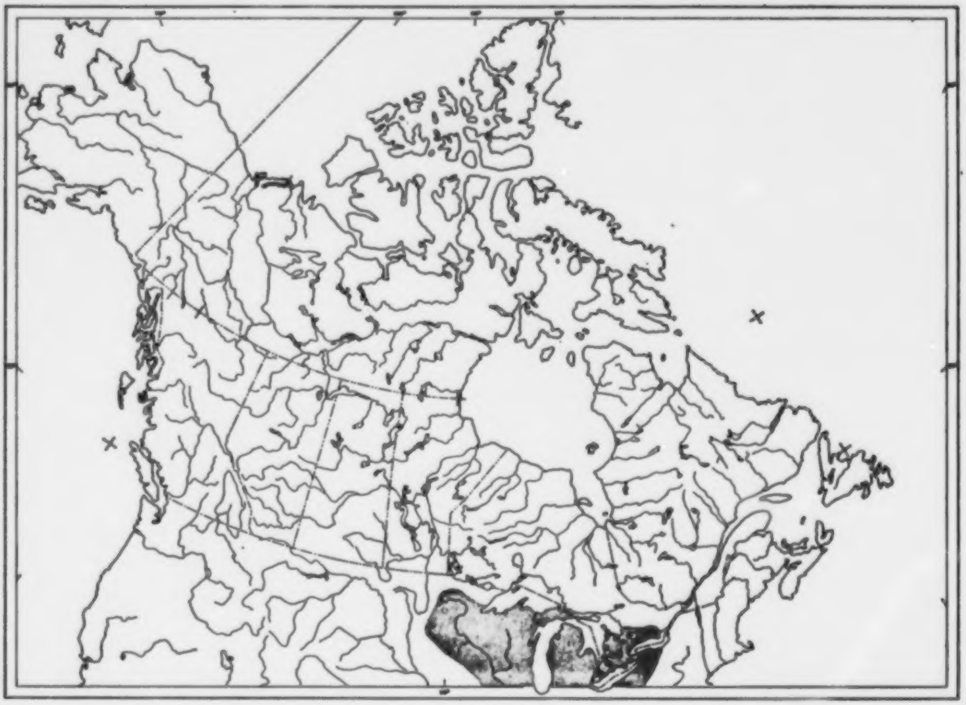


Description Body small, laterally compressed, robust, total length about 1 inch (25 mm), greatest body depth 14.0–19.1% of total length. Head triangular, its length 20.5–22.1% of total length, gill membranes rather broadly but delicately joined, free from isthmus, meeting at an obtuse angle; eye moderate to large, its diameter 22.2–28.9% of head length; snout length, less than eye diameter, 15.4–22.0% of head length; premaxillaries not protractile, bound to snout by narrow frenum; mouth small, maxillaries extending posteriorly barely to anterior margin of eye; teeth in brushlike bands on upper and lower jaws, outer teeth enlarged and widely spaced, inner teeth smaller and more crowded, size of teeth and spacing decreases toward rear of tooth band. Branchiostegal rays usually 5,5(8), sometimes 6,6(1). Fins: dorsals 2, first dorsal spiny, spines relatively strong, spines 6(9), or 7(10), second dorsal soft rayed, higher than spiny dorsal, rays 8(11) or 9(8), fins separated but very close together; caudal fin rounded and distinctly barred; anal fin well developed with 1(7) or 2(12) spines and 5(14) or 6(5) soft rays; pelvics inserted low on ventral surface, becoming enlarged on breeding males, with a sheet of skin extending outward and enlarging the width of the fin even to the outer base, this development not on females (*see* Petravicz 1936, for further details and illustration); pectoral rays relatively small, fanlike and rounded. Scales ctenoid, cheeks, opercles and breast naked; lateral line absent and only 1 pored scale in specimens examined; scales in lateral series 24–32; swim bladder absent. Vertebrae 31(4), 32(4), or 33(1).

Colour Overall colouration brownish, back and sides sprinkled with darker brown spots; a short, distinct, dorsal stripe anterior to first dorsal fin; 8–10 squarish, ill-defined blotches on sides. Ventral surface creamy with scattered brown speckling. The dorsal and caudal fins conspicuously speckled, anal and paired fins dusky. A prominent black suborbital bar. Breeding males colourful, with an orange spot on membrane between each dorsal spine, base and outer edge of spinous dorsal black; anal and pelvic fins rusty orange. Females, when breeding, may have yellowish caste to pelvic, pectoral, and anal fins.

Distribution The least darter ranges west from western part of Lake Ontario through tributaries of Lake Erie, through the Michigan–Huron basin, the southern drainage of Lake Superior, to the Mississippi River system in Minnesota; south to Kentucky, parts of Missouri and Arkansas, and southern Oklahoma.

In Canada this species has been found only in southern Ontario, in the drainages of western Lake Ontario, lakes Erie and St. Clair. It was first reported to occur in Canadian waters by Hubbs and Brown (1929) following a number of captures in the tributaries of lakes Ontario, Erie, and St. Clair. Although often overlooked in casual surveys, the least darter is not uncommon in suitable habitats within the area designated.



Biology Spawning takes place in spring, in May in Michigan (Winn 1958b) and probably May and June in Ontario although there appears to be no published observations. In Michigan, least darters move into shallow, weedy waters near shore in late April and May. The males occupy the vegetated area, while the females remain outside this area until ready to spawn. When the female enters the weedy area, she may be courted by several males, eventually one dominates, the female positions herself, almost and sometimes quite vertically, on the stem of a plant, the male mounts the female, maintaining his position atop the female by means of his modified pelvic fins which rest on the slope of the female's back, just in front of the dorsal fin. The mating fish vibrate, one egg is laid and fertilized, and the pair moves to a new site. The eggs are normally laid on the stems of plants but spawning may take place on the bottom although the fate of such eggs is unknown. After several eggs are deposited, the female retires to deeper water until again ready to spawn. The precise number of eggs deposited by a single female is not known but Winn (1958a) reported egg counts of pre-spawning females as 435–1102.

Males exhibit little territorialism and make no effort to protect the eggs, which, of course, are scattered anyway. The eggs average about 1 mm in diameter and hatch in about 6 days at temperatures of 64.4°–68.0° F (18°–20° C). Newly hatched young measured 3 mm total length. For additional details *see* Petravicz (1936).

The least darter is the smallest vertebrate in Canada and certainly the smallest fish. Adults average about 1 inch (25 mm) in total length and females, which average larger than males, may attain total lengths of 1.5 inches (38 mm). The largest female examined by us was 1.5 inches (38 mm) in total length.

Quiet, weedy waters of lakes, and slow-moving streams seem to be the preferred habitat, especially if there is a rich aquatic plant growth on a muddy bottom.

The least darter often exists undetected in a stream because of its small size and the difficulty of seining in weedy waters. As Hubbs and Brown (1929) noted many years ago, "It may often be most readily seined after the weeds have been most vigorously tramped on." A good-sized population in a Lake Erie tributary went undetected by us for 2 years despite repeated sampling, until we used a nylon seine that had a slightly smaller mesh than the standard quarter-inch cotton seine previously used.

Detailed food studies are not available but studies by Petravicz (1936) indicated that small crustaceans were readily consumed and it is assumed that other suitably small, benthic organisms are also eaten.

The four least darters examined by Bangham and Hunter (1939) from Lake Erie waters were not infected with parasites.

There are no records of parasitism of this species in Hoffman's 1967 publication.

Relation to man The least darter, the smallest Canadian fish, is of no known direct economic importance but its role and importance within its aquatic community is difficult to access because we know so little about it. Its spawning habit of laying single eggs on plant stems while in a vertical position, is certainly unusual among fishes, and indicates a niche specialization that warrants further study and better understanding.

Nomenclature

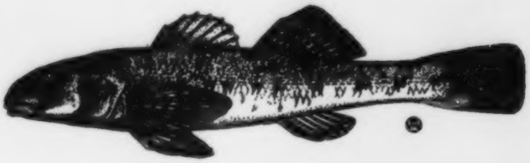
Etheostoma microperca — Jordan and Gilbert *in* Jordan 1888: 134 (type locality Northern Indiana to Minnesota)
Microperca punctulatum Putnam — Jordan and Evermann 1896–1900: 1104
Microperca punctulata Putnam — Hubbs and Brown 1929: 50
Microperca microperca (Jordan) — Speirs 1951: 16
Etheostoma microperca Jordan and Gilbert — Bailey 1951: 195

Etymology *Etheostoma* — from *etheo* — to strain, *stoma* — mouth; *microperca* — small perch.

Common names Least darter. French common name: *petit dard*.

JOHNNY DARTER

Etheostoma nigrum Rafinesque



Description Body slender, elongate, average total length to about 2.3 inches (58 mm), body not markedly compressed laterally, greatest body depth 12.1–16.3% of total length. Head bluntly rounded, its length 19.8–21.9% of total length, gill membranes narrowly joined, meeting at an acute angle and free from isthmus, opercle with a small, sharp spine posteriorly; eye moderate, its diameter 23.0–29.4% of head length; snout blunt, rounded, projecting beyond lower jaw, snout length 23.3–29.5% of head length; premaxillaries protractile; mouth moderate, lower jaw included in upper, maxillary extending posteriorly to anterior edge of orbit; teeth in brushlike bands in upper and lower jaws, generally small, but outer teeth are largest and most widely spaced, inner teeth small and closely set, teeth not decreasing greatly posteriorly. Branchiostegal rays 6,6(18), 6,7(1). Fins: dorsals 2, first dorsal spiny, spines relatively strong, spines usually 8(12) or 9(26), seldom 10(2), second dorsal soft rayed, slightly higher than first dorsal, rays 10(1), 11(4), 12(22), 13(12), or 14(1), western counts appear to be high, dorsal fins practically conjoined, barely separated; caudal decidedly square, or truncate; anal usually with 1(40) (but rarely first ray not serially divided and could be counted as second spine) and 7(1), 8(6), 9(24), or 10(9) rays; pelvics rather small, rounded; pectorals large and fanlike, rays usually 12. Scales ctenoid, cheeks and nape usually naked, opercles usually scaled, breast usually naked, belly scaled or naked; lateral line complete, scales 41–52, counts higher in west. Vertebrae 37(5), 38(10), or 39(4).

Colour The overall body colour is generally pale brown or straw coloured, sometimes yellowish or even with a green tint, depending on habitat. On the back are about 6 saddle-like darker markings, and between them the back is variously speckled with brown or dark brown. Along the midline of the sides are a series of 7–12 dark, distinctive M-, X-, or W-shaped marks. Breeding males become very black, especially on the anterior half of the body, obscuring the distinctive lateral marks. Second dorsal, caudal, and, to a lesser extent, the first dorsal and pectoral fins are barred or speckled with brown markings. Young fish are usually pale.

Systematic notes Historically the johnny darter, *Etheostoma (Boleosoma) nigrum*, has been considered a wide-ranging, variable species, composed of many subspecies. Based largely on the work of Hubbs and Lagler (1941), Dymond (1947) outlined the proposed distribution of subspecies inhabiting Canadian waters as follows:

Boleosoma nigrum nigrum (central johnny darter) —
Saskatchewan to western Quebec

B. n. olmstedi (tessellated johnny darter) —
from Ottawa River and eastern Ontario to western limits of Maritime Provinces (there are no records of occurrence in any Maritime Province)

B. n. eulepis (scaly johnny darter) —
in lakes Erie, St. Clair, and Detroit River

The primary features distinguishing these subspecies were the presence or absence of scales on cheeks, opercles, and breast, and the number of rays and the markings on the second dorsal fin. As early as 1913, Cockerell attempted to distinguish *nigrum olmstedi* on structural characters, in this case, the apical ctenii of the scales.

In a review of the status of *E. nigrum nigrum* and *E. nigrum eulepis*, in Minnesota, Underhill (1963) concluded that it was undesirable to continue to recognize the subspecies *E. n. eulepis* noting that, although the polymorphic nature of *Etheostoma nigrum* was unquestioned, the recognition of such polymorphism with subspecific names served no useful purpose.

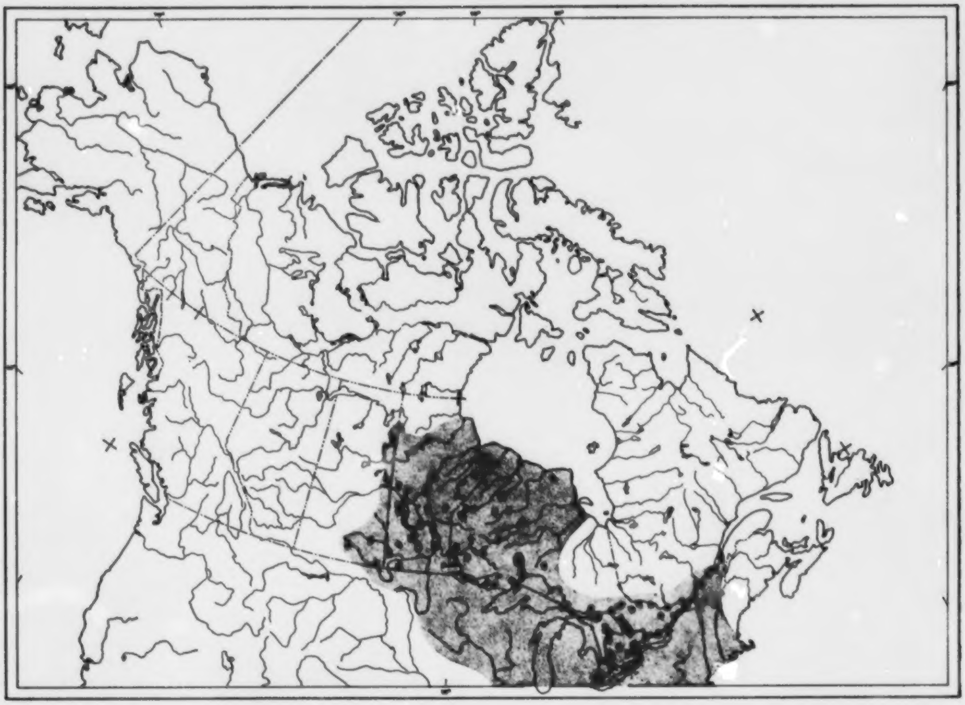
The subspecies *olmstedi* was studied by Stone (1947) and Cole (1965) both of whom considered *olmstedi* to warrant specific status. Cole (1967), in a comprehensive study of this new species, considered it to be composed of four subspecies. Few specimens were examined by Cole from Canadian waters. One sample, from the confluence of the Ottawa and St. Lawrence rivers, although identified as *Etheostoma olmstedi* (instead of *E. n. olmstedi* as formerly) was considered to consist of intergrades of two subspecies of *E. olmstedi*, *E. o. atromaculatum* × *E. o. olmstedi*. Indeed, all populations of the New York watershed of Lake Ontario and the St. Lawrence River, including the Lake Champlain drainage, were considered to be intergrades of these two subspecies.

The characters proposed by Cole (1967, p. 33) to differentiate *E. nigrum* and *E. olmstedi*, are presented in the following table.

Real difficulty is experienced, however, if one attempts to assign Canadian material to the taxonomic units proposed. Before meaningful statements about the systematics of *E. nigrum* in Canada can be made, rather thorough morphometric and meristic descriptions of the populations are required, and these have not yet been attempted. However, until such data are available, nothing is to be gained by changing names when we can still communicate effectively, with minimal confusion, by referring Canadian johnny darters to the species *Etheostoma nigrum*. The polymorphic nature of johnny darters is obvious enough, but what this means — whether the variation is somatic or genetic — is yet to be determined.

Distribution In Canada, the johnny darter ranges eastward to the mouth of Rivière Ouelle, on the south shore of the St. Lawrence River, and to St. Petronille, Ile d'Orléans, on the north shore. (J. Bergeron personal communication). It occurs in southern Quebec in the Lake Champlain area, in the Ottawa River, up the St. Lawrence River and throughout the Great Lakes area. It ranges northward in Ontario to the Hudson and James Bay drainages (not reported for the Abitibi River drainage), west to Lake of the Woods.

	E. olmstedi	*E. nigrum*
Pectoral rays	usually 13, often 12	usually 11 or 12
Second dorsal rays	usually 12–14	usually 10–12
Scales above lat. line	usually 4 or 5	usually 3 or 4
Scales below lat. line	north — usually 7 or 8 south — usually 6 or 7	usually 6 or 7
Infraorbital canal	usually complete, 8 pores	usually interrupted, 4 + 2 pores
Preoperculomandibular canal	usually 10 or 11 pores	usually 9 pores
Breeding males	darker, but not blackened	considerably blackened
Pelvic spines and rays in breeding males	ray tips slightly enlarged and whitened	tips grossly knoblike and whitened
Pectoral and pelvic fins	widely pointed	short and rounded
Mouth	slightly oblique and subterminal	horizontal and terminal
Snout	subconical, slightly inclined	rounded before eyes, almost vertical at mouth
X- and W-lateral marks on side of body	9–11	6 or 7



In Manitoba it occurs throughout the province north to the Churchill River area, in Southern Indian Lake.

In Saskatchewan it ranges from the Souris River in the south to Reindeer Lake (57°15'N, 102°40'W) of the Churchill River region in the north, but is generally restricted to eastern Saskatchewan. A collection (ROM 16624) from Loverin Lake near Chamberlain (50°50' N, 105°34' W) represents the western limit of range for the species.

Biology Spawning occurs in the spring, the exact time depending on local conditions. Toner (1943) wrote that he observed spawning in the flume of a hydro plant at Gananoque, Ont., as early as April 26, in 1935. Richardson (1935) did not observe spawning in the eastern townships of southern Quebec but caught gravid adults only during the latter part of May, never later, and Dymond (1926) said spawning occurred in June in Lake Nipigon. Over much of the southern part of the Canadian range, the johnny darter probably spawns in May, but possibly later farther north.

Observations on spawning in Canadian waters are few and scattered. The following information on spawning habits is derived largely from Winn (1958a,b), whose studies were conducted in southern Michigan. Males move onto the spawning grounds in April, earlier than the females. They select their territories and proceed to clean off the underside of the rock, picked as the nesting site, by moving around under the rock upside down. The males become darker during this period. Females do not enter the male's territory until ready to spawn, and when they do, they are met by a male who usually precedes the female under the rock. The male commences at once to move about under the rock, upside down. If courting is successful, the female moves in under the rock, turns upside down, and the pair move over the rock beside each other. Contact with each other is maintained by pectoral fins or other parts. The female pauses to deposit an egg every few seconds. The male, moving along beside her, apparently fertilizes the egg immediately after it is deposited. Females leave the nest when finished egg laying, which apparently consists of depositing clutches of 30–200 eggs at each of five or six spawning sessions. Larger females lay a larger number of eggs.

Males guard the eggs, moving over them, thus keeping them free of silt, and, when upright, fanning with their pectoral fins to maintain a flow of water. Eggs that develop fungus are eaten.

There may be considerable variation in the selection of nesting sites, depending on the kind available. Also, experimental evidence indicates that the male guards the place, rather than the eggs, for if the nesting stone and its eggs are removed, he will remain on site, still guarding the place where the nest had been (Atz 1940; Winn 1958a, b). The eggs are adhesive and measure about 1.5 mm in diameter. Hatching occurs in 5–8 days at temperatures of 71.6°–75.2° F (22°–24° C). A number of larval stages, up to 15 mm long, were described and illustrated by Fish (1932).

Johnny darters may be aged by scale examination as demonstrated by Raney and Lachner (1943) for New York populations and Karr (1963) for some populations in Iowa. Males grow to a larger size than females but, in the New York study, females lived longer than males, reaching age 4 while males did not live beyond age 3. Mature males larger than 2.7 inches (69 mm) total length, have not been seen by us but many specimens in the 65–69 mm range have been examined.

Johnny darters inhabit a wide variety of aquatic habitats but seem to be most common in waters of moderate or no current, over a bottom of sand, sand and gravel, or sand and silt, but do inhabit weedy areas or gravel riffles of streams. They are less demanding in habitat requirements than most other darters. Although they are usually associated with inshore waters, specimens have been recorded to depths of 138 feet in the Great Lakes.

Young johnny darters consume large numbers of copepods and small midge larvae, with lesser amounts of cladocerans. Copepods may remain an important food source but midge and mayfly larvae dominate the diet. Bottom organic debris and silt form significant dietary items for all sizes. Turner (1921) noted that the diet changed little throughout various localities in Michigan.

Johnny darters fall prey to many larger fishes and have been recorded in stomachs of lake trout, burbot, white perch, smallmouth bass, and walleye to name a few. In July, 1947, five were found in the stomach of a large whitefish caught in eastern Lake Erie. The extent to which the johnny darter contributes to aquatic food chains is not well understood but there can be no doubt that this abundant little darter makes a vital contribution to the conversion of benthic organisms and detritus to a higher life form.

Bangham and Hunter (1939) examined 7 johnny darters from the east end of Lake Erie and found 2 infected. Parasites identified were trematodes *Clinostomum marginatum*, *Neascus* sp., and the cestode *Proteocephalus pearsei*. Of the 16 they examined from the west end of the lake, 14 contained parasites as follows: trematodes *Leuceruthrus* sp., (immature form), and *Neascus vancleavei*, and nematodes *Agamonema* sp.

All 39 specimens examined by Bangham (1955) in the Lake Huron and Manitoulin Island area were parasitized. Parasites included trematodes (7), nematodes (3), acanthocephalans (2), cestodes (1), and leeches (1).

Hoffman (1967) published a long list of parasites infecting the johnny darter, which included: protozoans (3), trematodes (23), cestodes (6), nematodes (5), acanthocephalans (5), leeches (1), and molluscs (1).

Relation to man The most important role of the johnny darter is probably as a converter of small benthic materials to larger forms within the aquatic community and, thus, to serve as food for larger fishes. It is also a most useful species for behavioural studies in the laboratory and may be easily maintained in aquaria.

Nomenclature

Etheostoma nigra — Rafinesque 1820c: 37 (type locality Green River, Ky.)

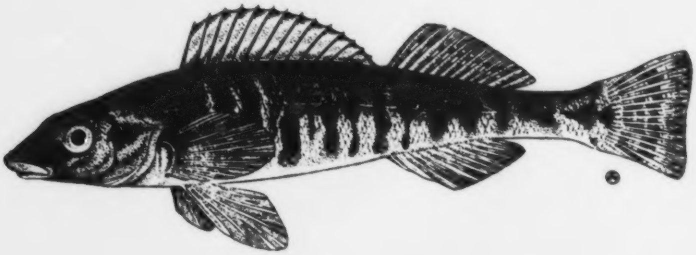
Boleosoma maculatum Agass. — Agassiz 1850: 305
Boleosoma nigrum (Rafinesque) — Jordan and Evermann 1896–1900: 1056
Etheostoma nigrum Rafinesque — Eigenmann and Eigenmann 1892: 962
— Bailey 1951: 195
— Bailey 1954: 140

Etymology *Etheostoma* — from *etheo* — to strain, *stoma* — mouth; *nigrum*, from *niger* — black.

Common names Johnny darter, central johnny darter. French common name: *raseux-de-terre.*

LOGPERCH

Percina caprodes (Rafinesque)



Description Body elongate, tubular, average length about 3.5 inches (89 mm), not noticeably compressed laterally except posteriorly, greatest body depth 12.4–17.8% of total length. Head conical, pointed, its length 19.5–23.9% of total length, gill membranes narrowly joined at an acute angle; eye diameter 22–28% of head length; snout elongate, pointed, extending beyond lower jaw, its length 29.5–36.0% of head length; premaxillaries not protractile, bound to snout by a frenum; mouth small, distinctly inferior, maxillary not extending posteriorly to anterior margin of eye; teeth in brushlike bands on upper and lower jaws, outer teeth larger and more widely spaced, inner teeth smaller and crowded; teeth decrease in size posteriorly. Branchiostegal rays 6,6(8), 6,7(2). Fins: dorsals 2, first dorsal spiny, spines strong, usually 14(23), or 15(18), sometimes 13(3) or 16(1), second dorsal soft rayed, and slightly higher than first dorsal, rays 15(19) or 16(14), sometimes 14(6), 17(3), or 18(1), fins narrowly separated by one scale row; caudal truncate or square, not forked; anal fin with 2(39), rarely 1(4), spines, soft rays 9(5), 10(23), 11(14), or 12(1), the fin about equal to second dorsal in size; pelvics moderate, much smaller than pectorals, not obviously pointed; pectorals large, fanlike, rays 13 or 14. Scales ctenoid, cheeks and opercles scaled, breast naked, belly usually naked on females, males usually with a row of scales on midline; lateral line complete, scales ranging from 71–85; swim bladder developed in posterior part of body cavity. Vertebrae 40(1), 41(7), 42(8).

Breeding tubercles on ventral scale rows of males only.

Colour The usual overall colouration is yellowish green with dark olive or black markings. Specimens taken in deeper water of large lakes are often gray-green in overall colouration. There are 8–10 saddle-shaped marks on the back, separated by lines or patches of yellow; continuous with, or seeming to alternate with the saddle marks are vertical bars that expand, droplike on their lower ends, and terminate below the middle of the sides; the bars do not extend onto the ventral surface. The dorsal and caudal fins are lightly barred, with splashes of yellow on the fin membranes. Fins on ventral surface may be colourless, or with flecks of pigment on membranes and yellow on the fin rays. A conspicuous round, black spot occurs at the caudal fin base. A vague or weak suborbital bar usually present. Colours intensify on breeding males.

Systematic notes Three subspecies of logperch have been described: the typical subspecies *P. c. caprodes* ranges generally south of the Great Lakes, *P. c. carbonaria*, occurring from Florida to Texas, the most southerly part of the range, and *P. c. semifasciata*, the northern logperch. The form occurring throughout Canada is considered to be *P. c. semifasciata*.

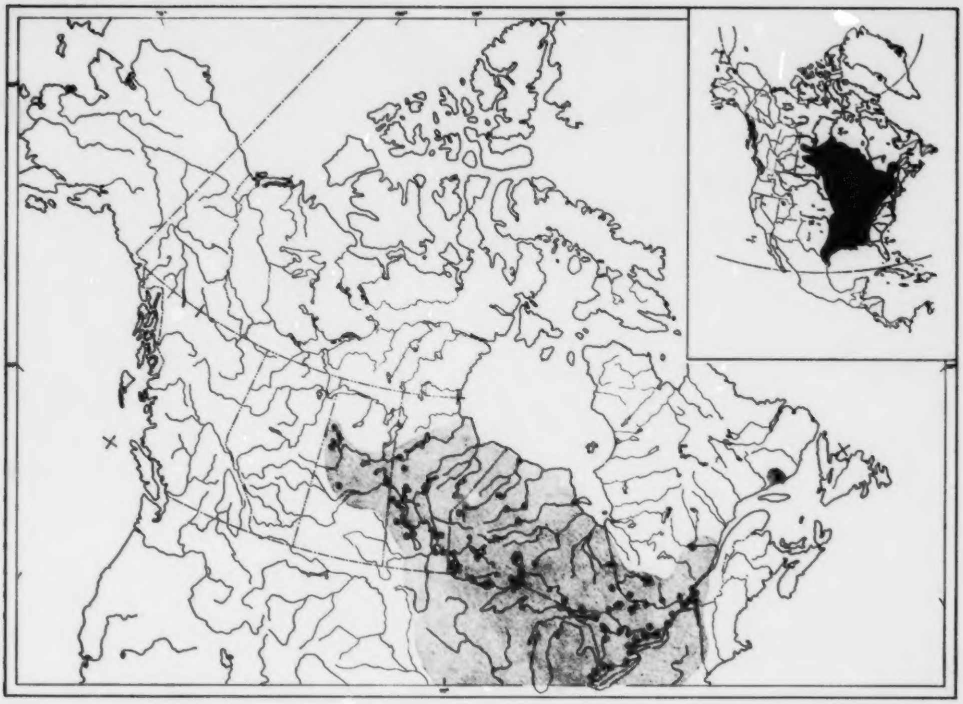
Hybrids of logperch with the blackside darter and channel darter were reported by Hubbs (1926), and with the river darter by Carlander (1941).

Distribution The logperch is a wide-ranging species in North America and occurs from St. Lawrence River tributaries of eastern Quebec (about 63° W) southwestward through Lake Champlain, the Great Lakes, west to Saskatchewan and south through the Mississippi River system to the Rio Grande River in southern Texas. It was apparently inadvertently introduced into California waters in 1953.

It was reported from Aguanus River on the north shore of the Gulf of St. Lawrence, at 63°W, which may represent isolated eastern populations. Also reported from Lac St. Jean, Que., and west in the St. Lawrence River, Great Lakes system throughout all of Ontario, including Lake Abitibi and the Hudson Bay lowlands north to James and Hudson bays. In Manitoba throughout the southern part, north to the Churchill River drainage, and in Saskatchewan in the Churchill and Saskatchewan River areas, west to the western limit of range in Delaronde, Canoe, and Churchill lakes.

Biology Logperch spawn in late spring, usually commencing in June. There are few observations of spawning in Canadian waters but Winn (1958b) gave a detailed description of spawning in Douglas Lake, Mich., where Reighard (1913) over 40 years earlier observed spawning by the same species.

Winn noted that the logperch populations remained in deep water offshore until late June when they moved to sandy inshore shallows. A few to several hundred males gathered in a large school on the sand shoals in depths of 4–79 inches (10–200 cm). Winn stated that, in general, females remained outside the school until ready to spawn, when they swam through the school of males and out again. One female may be followed by a few or many males. When she stops on the bottom, one of the males will alight on her back, pelvic fins placed ahead of her first dorsal, his caudal fin depressed beside hers. Both fish vibrate, which tends to partly bury them in the sand, the eggs are extruded and fertilized, and a cloud of sand surrounds the vibrating pair. Winn estimated that 10–20 eggs were released at each spawning, after



which the female retired to deeper water and the male rejoined the school. The eggs were abandoned. Each female may spawn several times, each time with a different male. Although males would pursue each other, none were seen to actually attack another and no individual territorialism was exhibited. Both Reighard and Winn remarked that non-spawning males, attracted to the spawning pair, eagerly ate all eggs that were not buried. The exact number of eggs deposited is difficult to ascertain, but counts of eggs in pre-spawning females ranged from 1060 to 3085, the larger number in the larger female. The eggs are colourless and measure 1.3 mm in diameter. There are few data on developmental rates in northern latitudes but Hubbs (1961), working on Texas specimens, noted that embryos survived at temperatures between 71.6°–78.8° F (22°–26° C). Larval stages were described and four sizes of embryos (6.6, 12.1, 14.2, and 20.5 mm) were illustrated by Fish (1932).

We have no information on rates of growth in Canadian waters and few from elsewhere. Males and females attain about the same maximum size and presumably grow at about the same rate. Large adults range around 4 inches (102 mm) total length. The largest logperch examined was a female 4.8 inches (121 mm) in total length, from Lake Ontario watershed, but females over 4.5 inches (115 mm) were examined from Lake Winnipeg.

Logperch inhabit sand, gravel, or rocky beaches in lakes and over similar bottom in larger rivers, sometimes in rather swift water as Dymond (1926) noted in the Lake Nipigon region. They tend to stay offshore in water deeper than 3–4 feet and thus readily escape a survey seine and so are often said, mistakenly, to be uncommon. Indeed, they have been captured by otter trawl at depths of 131 feet in Lake Erie (Trautman 1957).

Young logperch feed on a variety of small organisms but principally upon cladocerans and copepods. As they grow, aquatic insect larvae, particularly mayfly and midge larvae, become increasingly important (Turner 1921).

The feeding ecology of adult logperch in Lake Opinicon, Ont., was studied by Keast and Webb (1966), who reported the following percentages, by volume, of various food organisms: chironomid or midge larvae (to 70% in some months), amphipods (to 40%), isopods (to 20%), dragonfly nymphs (to 15%), and mayfly nymphs (to 10%). These results are in accord with the food in other regions reported by Pearse (1918), Turner (1921), and Dobie (1959). Keast and Webb noted that the protruding and rounded snout was used to roll over small stones, leaves, and other objects on bottom to obtain the organisms beneath them.

One of the serious predators on logperch are logperch themselves, specifically the consumption by non-spawning males of unburied or lightly buried eggs. Among the earlier observers of this phenomenon were Ellis and Roe (1917), who also reported the eating of logperch eggs by white suckers (*C. commersoni*). Logperch are undoubtedly eaten by a variety of piscivorous fishes and have been reported in stomachs of lake trout (Van Oosten and Deason 1938), walleye (Raney and Lachner 1942), and northern pike (Greeley 1927). But the extent to which they enter into the diet of Canadian fishes is unknown.

Bangham and Hunter (1939) examined 45 logperch from Lake Erie. Nine of the 13 fish from the east end of the lake were parasitized and 20 of the 32 specimens from the west end were infected. Parasites identified were trematodes *Diplostomum* sp., *Clinostomum marginatum*, *Neascus* sp., *Leuceruthrus* sp., *Allocreadium boleosomi*, *Tetracotyle* sp.; cestodes *Bothriocephalus cuspidatus*, *Proteocephalus stizostethi* (larval or immature form of both species), *Proteocephalus pearsei*; nematodes *Camallanus oxycephalus*, *Agamonema* sp.; acanthocephalan *Leptorhynchoides thecatus*; and a leech, *Piscicola punctata*.

Bangham (1955) examined one specimen from South Bay, Lake Huron, infected with Gyrodactyloidea, and the encysted larval form of the acanthocephalan, *Pomphorhynchus bulbocolli*.

Guilford (1963) described a new species of Myxosporidia, *Myxosoma scleroperca*, located within the sclerotic cartilage of logperch collected from Green Bay, Lake Michigan.

Hoffman (1967) listed many species of parasites as follows: protozoans (2), trematodes (10), cestodes (6), nematodes (4), acanthocephalans (5), leeches (2).

Relation to man The logperch is occasionally used as live bait by anglers but cannot be held alive in a minnow pail for long. It is eaten by predaceous game and commercial fishes but its importance in this role is unknown. It can easily be mistaken in stomach contents for yellow perch, and possibly, often is.

Nomenclature

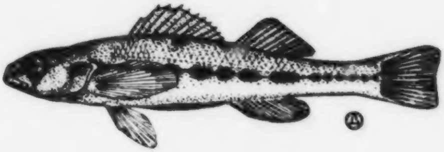
Sciaena caprodes — Rafinesque 1818c: 354 (type locality Ohio River)
Etheostoma caprodes — Rafinesque 1820c: 38
Pileoma semifasciatum — DeKay 1842: 16
Pileoma zebra — Agassiz 1850: 308
Pileoma Fasciatum — Small 1865: 15 (taken in the Don River in great numbers)
Percina caprodes (Rafinesque) — Jordan and Evermann 1896–1900: 1026

Etymology *Percina* — a diminutive of *Perca*; *caprodes* — pig, resemblance, in reference to snout.

Common names Logperch, zebra fish, log perch, Manitou darter. French common name: *dard-perche*.

CHANNEL DARTER

Percina copelandi (Jordan)



Description Body elongate, slender, average total length about 1.5 inches (38 mm), not noticeably compressed laterally, body not deep, greatest body depth 12.8–15.6% of total length, and less than head length. Head moderate, its length 20.0–21.2% of total length, opercle with a flat, inconspicuous spine posteriorly, gill membranes narrowly joined at an acute angle; eye diameter 26.8–28.3% of head length; snout distinctly downcurved, its length 24.5–28.5% of head length, projecting slightly beyond premaxilla; premaxillaries protractile, with a distinct groove across snout (but *see* Winn 1953, p. 26, who reported 13% with a frenum); mouth moderate, maxillary extending posteriorly to below pupil, jaws nearly equal or lower jaw slightly included in upper; teeth small, pointed, in brushlike bands on upper and lower jaws, bands several teeth wide, outer teeth larger and more widely spaced, inner teeth small and closely set. Branchiostegal rays 6,6(3). Fins: dorsals 2, first dorsal spiny, spines strong, spines usually 11, second dorsal soft rayed, slightly higher than spiny dorsal, rays 12, 13, or 14, dorsal fins distinctly separated by at least 4 scale rows; caudal shallowly forked, emarginate; anal with 2 spines and 9 or 10 soft rays; pelvics small, narrow; pectorals rounded, fanlike, rays about 13. Scales ctenoid, cheeks naked, opercles scaled, breast naked except for enlarged scale at apex of pelvic girdle and often between pelvics; enlarged row of scales along midline of belly, or belly naked; lateral line complete, scales usually 43–51; swim bladder usually rudimentary. Vertebrae 37 or 38.

Colour Overall colouration is light sand, back with brown speckles, and along the midline of each side is a series of small brown, round or oblong blotches usually joined together by a thin line. The fins are clear or only lightly speckled. Breeding males are dusky, becoming dark about the head.

Distribution The channel darter is found in the upper St. Lawrence River–Lake Champlain area, Lake Erie, and Lake Huron, along the eastern margin of the lower peninsula of Michigan; west of the Appalachian Mountains south to Alabama, Arkansas, Oklahoma, and southeastern Kansas.

The channel darter is rare in Canada. In Quebec it has been reported in the tributaries of the upper St. Lawrence River as far east as the Nicolet and St. Francois rivers flowing into Lac St. Pierre, and also in the Lachine Rapids and the Chateauguay River (Cuerrier et al. 1946); in Ontario from many localities along the shores of Lake Erie such as near Port Dover, Port Burwell, Erieau, and Point Pelee, and also from the Detroit River.

Biology Spawning takes place in the spring. A thorough discussion was given by Winn (1953) for a population in the Cheboygan River, Mich. Winn observed spawning between July 9 and 23, when water temperatures ranged from 69°–72° F (20.5° –21.2° C). He was able to determine that at least weakly flowing water was essential for spawning over the gravel-bottomed area, and that spawning ceased if the current flow was interrupted. The males established territories, each of which usually had at least one large rock in the centre, and maintained a station behind the rocks. The size of the territory varied greatly depending on the space available, but 30 territories were counted in a space 10 by 30 feet. When females were ready to spawn, they moved into the region where the males held territories. After initial courtship, during which the male attempted to drive the female toward the centre of the territory, spawning occurred between small rocks or in fine gravel behind the central rock, but not in fine sand. The female works herself into the gravel, and the male perches on top of her, with one pelvic fin on either side of her and his caudal fin depressed beside hers. The eggs are deposited, fertilized from this position, and the parents depart, leaving the eggs buried in the gravel. By excavating abandoned eggs Winn concluded that 4–10 eggs were extruded during one mating session. The females may mate with a number of males during the spawning season. The total number of eggs deposited by a single female would be difficult to determine but Winn reported egg number to range from 357 to 415, based on egg counts from three females. Ripe eggs measured 1.4 mm in diameter but no data were obtained on their rate of development. Larval development was described by Fish (1932) who illustrated a 6.1 mm specimen.

Rates of growth are not available but males normally grow larger than females. The largest specimen examined by us was a male 2.4 inches (61 mm) total length.

The channel darter inhabits sand and gravel beaches, and bars associated with such beaches, where the current is slow or sluggish. This is the typical habitat along Lake Erie shores (Scott, D.C. 1955; Trautman 1957).

Analyses of stomach contents of specimens from the Bass Islands region of Lake Erie by Turner (1921) indicated that the species fed primarily upon mayfly and midge larvae but ingested large amounts of algae and bottom debris as well. There was little difference in the diet of young and adults; all sizes were strongly benthic feeders.

Bangham and Hunter (1939) examined 34 specimens from the west end of Lake Erie and found only 8 parasitized. Parasites identified were trematodes *Neascus* sp., *Lebouria cooperi*, the cestode *Bothriocephalus cuspidatus*, and a nematode *Camallanus oxycephalus*.

Hoffman (1967) listed trematodes (2), cestodes (1), and nematodes (1).

Relation to man The role played by this small vertebrate in our aquatic environment is not well known. Although we know of no direct economic importance, indirectly its significance, while possibly slight, is of interest because of its benthic food habits and ingestion of algae and bottom debris.

Nomenclature

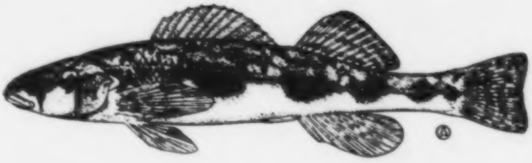
Rheocrypta copelandi	— Jordan 1877a: 9 (type locality White River, 5 miles N of Indianapolis, Ind.)
Cottogaster copelandi (Jordan)	— Jordan and Evermann 1896–1900: 1045
Hadropterus copelandi (Jordan)	— Hubbs and Lagler 1958: 107
Percina copelandi	— Bailey et al. 1954: 140
	— Hubbs and Lagler 1964: vii

Etymology *Percina* — a diminutive of *Perca*; *copelandi* — after its discoverer, H. E. Copeland.

Common names Channel darter, Copeland's darter. French common name: *dard gris*.

BLACKSIDE DARTER

Percina maculata (Girard)

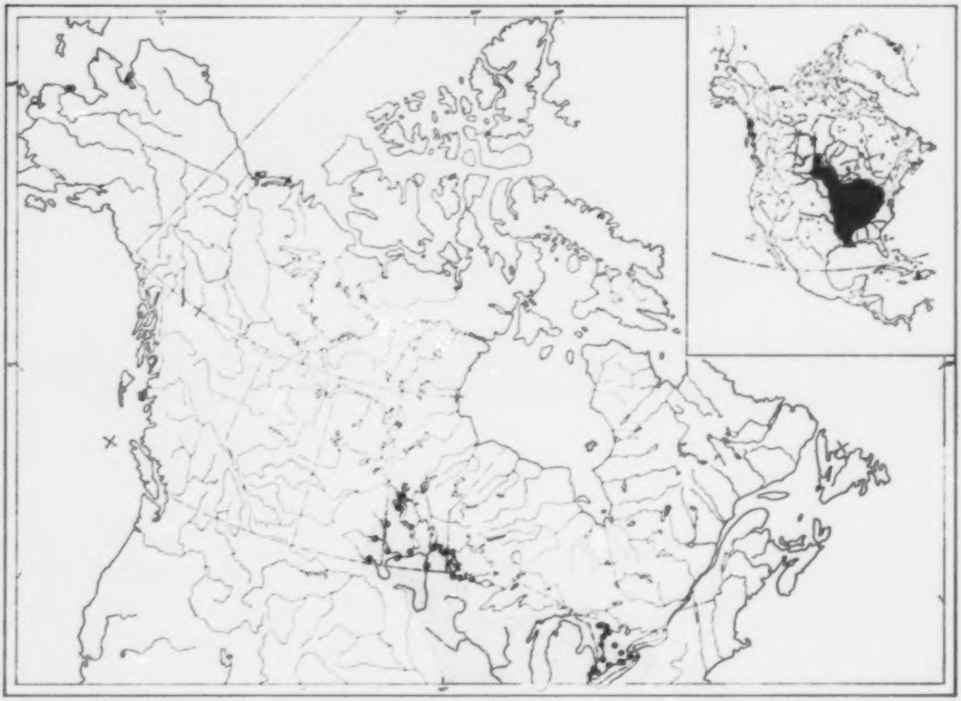


Description Body rather robust, average total length about 2.3 inches (58 mm), somewhat compressed laterally, greatest body depth 13.6–17.3% of total length. Head triangular, pointed, its length 20.6–24.0% of total length, gill membranes narrowly joined at an acute angle, opercle with a small, sharp spine posteriorly; eye moderate, its diameter 21.6–29.9% of head length; snout sharp, its length 22.5–27.7% of head length, projecting slightly beyond lower jaw; premaxillaries not protractile, bound to snout by a distinct frenum; mouth large, upper jaw protruding, maxillary extending posteriorly past the anterior margin of the orbit; teeth in brush-like bands on upper and lower jaws, outer teeth larger and more widely spaced, inner teeth small, crowded, all teeth decreasing in size and number posteriorly. Branchiostegal rays 6,6(10). Fins: dorsals 2, first dorsal spiny, spines strong, usually 13(18) or 14(15), seldom 12(1) or 15(4), second dorsal soft rayed, slightly higher than first dorsal, rays usually 13(14) or 14(19), sometimes 11(1), 12(3), or 15(1), fins distinctly separated by about 3 scale rows; caudal well developed, slightly forked, lightly barred, a distinct black spot at base; anal with 2 spines and 9(5), 10(24), 11(8), or 13(1) soft rays, about same size as second dorsal; pelvics long, narrow, somewhat poined; pectorals long, rather narrow, somewhat pointed, rays usually 13, sometimes 14. Scales ctenoid, cheek and opercles scaled, a single row of enlarged scales along the midline of the belly, one between bases of pelvic fins and smaller one at apex of pelvic girdle; lateral line complete, straight, scales in lateral line 56–67 (*see Systematic notes*), swim bladder present. Vertebrae 41(11) or 42(7).

Colour Overall straw coloured, light olive, or olive-brown, with numerous dark blotches. On the back are 8 or 9 indistinct, dark, saddle-shaped markings, between and below these are many irregular blotches and vermiculations. Along the midline of the sides is a series of 5–7 elongate dark or black blotches, often clearly defined; these elongate black marks tend to coalesce, and are continuous with a black band that continues forward, around the head and across the snout, and terminates posteriorly with a distinct round black spot at the caudal fin base. There is a distinct, black, suborbital bar. Ventral surface of head and body white or creamy, without pigmentation. Spinous dorsal fin membranes suffused with black pigment at bases, becoming less intense distally. Second dorsal and caudal fins lightly barred. Spawning males without colours but black areas become intensified.

Systematic notes Examination of 38 specimens suggested that blackside darters in Manitoba have fewer dorsal spines and fewer scales than those in Ontario.

Distribution The blackside darter occurs from the western part of the Lake Ontario drainage west (excluding the Lake



Superior drainage) to North Dakota, Manitoba, and Saskatchewan; southward, to the west of the Appalachian Mountains to the Ozark region, the Gulf coast in Alabama, and northeastern Texas.

In Canada, the species occurs in the southwestern part of Ontario. There are no Ontario records for Lake Ontario. It is found in the tributaries of lakes Erie, St. Clair, and southern Lake Huron and is recorded from the Rainy River district but it does not occur in Lake Superior or its tributaries.

In Manitoba, it occurs in the Winnipeg, Red, and Assiniboine River drainages and from tributaries of Swan Lake; the northernmost record is from Big Eddy, near The Pas. In Saskatchewan it occurs in the Qu'Appelle drainage system and Souris River, its westernmost limit.

Biology Spawning occurs in spring, probably in May or June in Canada, although there is no supporting evidence. Petravicz (1938) and Winn (1958b) observed spawning in early May in southern Michigan, at temperatures of about 62° F (16.5° C). Adults move upstream on the approach of spawning season, the males gathering in gravel-bottomed pools or raceways, but not in riffles. The females remain in pools or quieter water immediately downstream from the males. When a female is ready to spawn, she moves upstream and is pursued by rival males. Spawning occurred at depths of 12 inches (30 cm) or more. Petravicz noted that the female usually initiated the spawning by selecting a suitable gravelly or sandy depression. She wriggled her body partly into the gravel, the male perched on her back, his caudal region depressed beside hers, and the eggs were deposited in the gravel and fertilized from this position. After a resting period, the spawning act was repeated several times with different males. The number of eggs, as recorded by Winn (1958a) from egg counts made on two prespawning females, ranged from 1000 to 1758. The eggs are large, colourless, about 2 mm in diameter. Petravicz (1938) reported a minimum incubation period of 142 hours, or about 6 days, but incubation temperature was not given. He described and illustrated newly hatched (5.75 mm total length) and 21 day-old postlarvae. Fish (1932) also described and illustrated the larvae.

There are no growth data for Canadian populations but Karr (1963) presented growth information for an Iowa population. Males and females grow at about the same rates and attain the same size. Karr considered this to be a relatively fast-growing species, attaining a maximum age of 4 years which, with our limited knowledge, seems relatively long lived among darters. The largest specimen examined by us was a male, 3.6 inches (92 mm) total length, from Norfolk County, Lake Erie.

The blackside darter is a stream species, inhabiting the quiet regions and pools of medium-sized, gravelly streams. Although the species is said to prefer clear waters, many of the Ontario streams containing this darter are quite turbid. This species is less benthic in its mode of life than many darters, and utilizes mid-depths, particularly when young.

Turner (1921) examined the food eaten by 11 specimens from Ohio waters and noted mayfly and midge larvae, corixid nymphs, copepods, and fish remains in the stomachs. These findings are in agreement with statements by Forbes and Richardson (1920) for Illinois.

Bangham and Hunter (1939) examined 2 specimens from the west end of Lake Erie and found one infected with the nematode *Camallanus oxycephalus*.

Relation to man The role of this darter in the ecological fabric of our streams is largely unknown. It may be quite numerous at times, within its restricted Canadian distribution, and at such times doubtless plays an important ecological role, particularly since it probably feeds on aquatic insect larvae. *See also Relation to man* for channel darter and rainbow darter.

Nomenclature

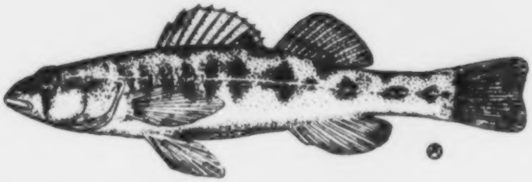
Alvordius maculatus — Girard 1860: 67 (type locality Fort Gratiot, L. Huron, Mich.)
Etheostoma aspro — Eigenmann and Eigenmann 1892: 962
Hadropterus aspro (Cope and Jordan) — Jordan and Evermann 1896–1900: 1032
Hadropterus maculatus Girard — Hubbs 1926: 59
Alvordius aspro Cope and Jordan — Hubbs 1926: 60
Percina maculata (Girard) — Bailey et al. 1954: 140
— Hubbs and Lagler 1964: vii

Etymology *Percina* — a diminutive of *Perca*; *maculata* — spotted.

Common names Blackside darter, black-sided darter. French common name: *dard noir*.

RIVER DARTER

Percina shumardi (Girard)



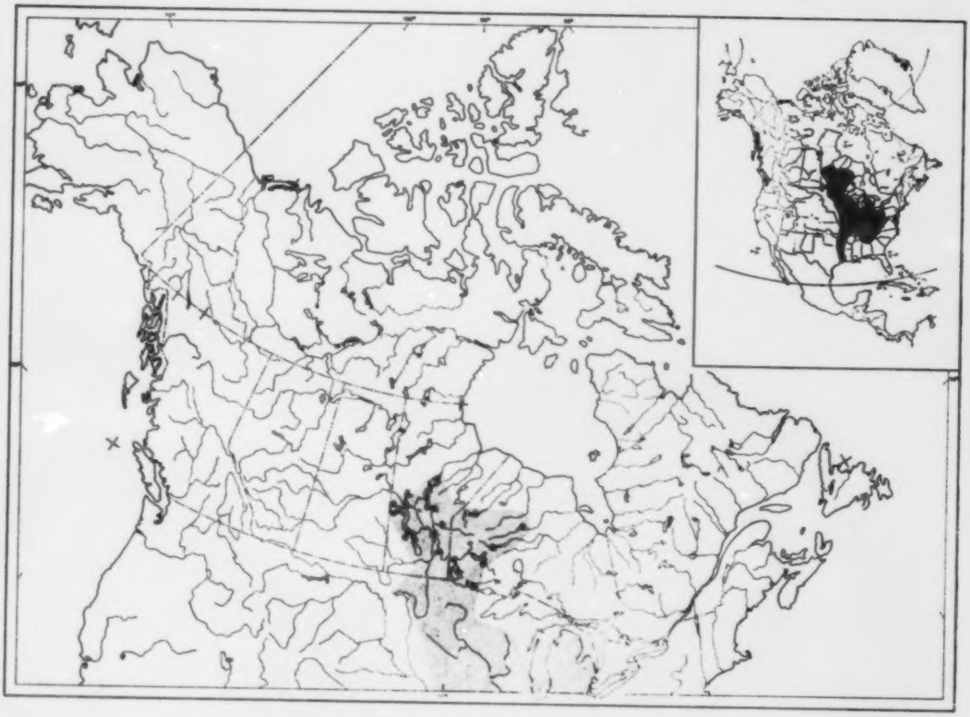
Description Body sturdy, slender, average total length about 2.2 inches (58 mm), somewhat compressed laterally, greatest body depth 10.3–16.0% of total length. Head length 20.2–24.6% of body length, gill membranes narrowly joined at an acute angle, opercle with a strong spine posteriorly; eye diameter 24.4–30.0% of head length; snout slightly projecting beyond lower jaw; premaxillaries usually bound to snout by a narrow frenum; mouth moderate, lower jaw barely included in upper jaw, maxillary extending posteriorly to, or slightly beyond, anterior margin of orbit; teeth in brushlike bands on upper and lower jaws, outer teeth larger and more widely spaced, inner teeth smaller and crowded; very gradual decrease in size of teeth posteriorly. Branchiostegal rays 6, 6, 6, 7, 7, 7. Fins: dorsals 2, first dorsal spiny, spines strong, usually 10(18), sometimes 9(3) or 11(4), second dorsal soft rayed, slightly higher than first dorsal, rays usually 13(11), 14(11) or 15(3), fins narrowly separated by about 1 scale row only; caudal fin shallowly forked; anal with 2 spines and usually 11(19), sometimes 10(3) or 12(2) rays, fin usually larger than second dorsal, and tip may reach almost to caudal fin on spawning males; pelvics moderate, pointed; pectorals fan-like, rounded, rays 13 or 14. Scales ctenoid, cheek and opercles scaled, breast usually scaleless, midline of belly scaled or scaleless; lateral line complete, scales 49–57. Vertebrae 37, 38, or 39.

Colour Light brown to dark olive brown overall; 7 or 8 weak, saddle marks on the back and 8–10 lateral blotches along midline of sides that often appear as short vertical bars. A distinct suborbital bar descending vertically from eye. A small, precise, caudal spot sometimes present. The most distinct markings are on spinous dorsal fin consisting of a dark blotch on membrane behind first spine and a larger and more conspicuous blotch extending over membrane connecting last three spines. Second dorsal and caudal fins only lightly speckled. Ventral surface, including anal, pelvic, and pectoral fins, without pigmentation. Spawning males darker overall and pigmented areas intensified.

Systematic notes The river darter was first reported from Canada by Eigenmann and Eigenmann (1892) on the basis of three specimens caught at Winnipeg, Man. The authors described it as a new species, *Etheostoma güntheri*. The specimens are still extant in the British Museum (Nat. Hist.), numbers 1892.12.30. 151–152–153. The first one, no. 151, a slender male 41.4 mm standard length, was designated as the lectotype by B. B. Collette. The species was first caught in Ontario in 1931 (Savage 1933).

Distribution The river darter ranges from south-central Canada southward through North Dakota (not South Dakota) and south of the Great Lakes in the upper Mississippi River system, thence to northern Alabama, Mississippi, and to eastern Kansas and Oklahoma, south in eastern Texas to the Gulf coast.

In Canada, it occurs in the Kenora district



of Ontario north to Lake Attawapiskat and Sandy Lake. There are no Lake Erie–Detroit River records for Ontario, but it is possible that it occurred in the area since it has been reported in the Detroit River. In Manitoba, it occurs in the Lake Winnipeg drainage area, in scattered localities, north to Sipiwesk Lake (55°05′N, 97°35′W), and west to Red Deer River and Lake Dauphin. The northern limit of range for the species is Sipiwesk Lake. The species does not appear to be common anywhere in Canada.

Biology There is no published information available on the biology of the river darter in Canada and little for the United States. It may be presumed that spawning occurs in the spring, possibly June or July in Manitoba and Ontario, and that the spawning behaviour does not differ greatly from that of other members of the genus *Percina*, particularly *maculata* and *copelandi*. The largest specimen examined was 2 inches (51 mm) in total length.

The habitat is primarily large rivers with a rubble- or boulder-strewn gravel bottom and a fair to moderate current. Specimens from the Lake Attawapiskat region were caught in the swift clear waters of the Drinking Martin River, over a bottom densely covered with boulders. Trautman (1957) noted that it also occurred in the silted, turbid tributaries of southwestern Lake Erie. It may also occur in lakes.

Although direct observations of its food habits are not available, it is most probable that the larvae of caddisflies, mayflies, midges, and blackflies form a significant part of its diet.

There are no published records of parasites of this species.

Relation to man Unknown, but *see Relation to man* for channel darter.

Nomenclature

Hadropterus shumardi — Girard 1860: 100 (type locality Arkansas River, near Fort Smith, Ark.)
Etheostoma güntheri — Eigenmann and Eigenmann 1892: 962
Cottogaster shumardi (Girard) — Jordan and Evermann 1896–1900: 1046
Imostoma shumardi Girard — Hubbs 1926: 62
Imostoma shumardi (Girard) — Dymond 1947: 27
Percina shumardi — Bailey et al. 1954: 140

Etymology *Percina* — a diminutive of *Perca*; *shumardi* — after its discoverer, Dr G. C. Shumard, surgeon of the Pacific railroad survey.

Common names River darter. French common name: *dard de rivière*.

Suggested Reading — Percidae

Pt. 1. Perch, walleye, sauger

Addison, W. D., and R. A. Ryder. 1970. An indexed bibliography of North American *Stizostedion* (Pisces, Percidae) species. Ont. Dep. Lands Forests Res. Inf. Pap. (Fish.) 38: 317 p.

Allen, K. R. 1935. The food and migration of the perch *(Perca fluviatilis)* in Windemere. J. Anim. Ecol. 4: 264–273.

Carlander, K. D. 1945. Age, growth, sexual maturity and population fluctuations of the yellow pike-perch *Stizostedion vitreum vitreum* (Mitchill), with reference to the commercial fisheries of Lake of the Woods, Minnesota. Trans. Amer. Fish. Soc. 73: 90–107.

1950. Growth rate studies of saugers, *Stizostedion canadense canadense* (Smith) and yellow perch, *Perca flavescens* (Mitchill) from Lake of the Woods, Minnesota. Trans. Amer. Fish. Soc. 79: 30–42.

Cleary, R. E. 1949. Life history and management of the yellow pikeperch, *Stizostedion vitreum vitreum* (Mitchill), of Clear Lake, Iowa. Iowa State Coll. J. Sci. 23: 195–208.

Collette, B. B. 1963. The subfamilies, tribes, and genera of the Percidae (Teleostei). Copeia 1963: 615–623.

Deason, H. J. 1933. Preliminary report on the growth rate, dominance, and maturity of the pike-perches *(Stizostedion)* of Lake Erie. Trans. Amer. Fish. Soc. 63: 348–360.

MS 1939. Morphometry and life history studies of the pike-perches *(Stizostedion)* of Lake Erie. Ph.D. Thesis. Univ. Michigan, Ann Arbor, Mich. 358 p.

El-Zarka, S. E. 1959. Fluctuations in the populations of yellow perch, *Perca flavescens* (Mitchill), in Saginaw Bay, Lake Huron. U.S. Fish Wildl. Serv. Fish Bull. 151, Vol. 59: 365–415.

Eschmeyer, P. H. 1950. The life history of the walleye, *Stizostedion vitreum vitreum* (Mitchill), in Michigan. Mich. Dep. Conserv. Inst. Fish. Res. Bull. 3: 99 p.

Forney, J. L. 1967. Estimates of biomass and mortality rates in a walleye population. N.Y. Fish Game J. 14: 176–192.

HERMAN, E., W. WISBY, L. WIEGERT, and M. BURDICK. 1959. The yellow perch. Its life history, ecology, and management. Wis. Conserv. Dep. Publ. 228: 14 p.

HILE, R. 1954. Fluctuations in growth and year-class strength of the walleyes in Saginaw Bay. U.S. Fish Wildl. Serv. Fish Bull. 91. Vol. 56: 5–59.

HILE, R., and F. W. JOBES. 1942. Age and growth of the yellow perch, *Perca flavescens* (Mitchill), in the Wisconsin waters of Green Bay and northern Lake Michigan. Pap. Mich. Acad. Sci. Arts Lett. 27: 241–266.

JOBES, F. W. 1952. Age, growth, and production of yellow perch in Lake Erie. U.S. Fish Wildl. Serv. Fish Bull. 70, Vol. 52: 205–266.

LEACH, G. C. 1928. Artificial propagation of pike perch, yellow perch, and pikes. U.S. Comm. Fish Rep. (1927). p. 1–27.

LECREN, E. D. 1958. Observations on the growth of perch (*Perca fluviatilis* L.) over twenty-two years with special reference to the effects of temperature and changes in population density. J. Anim. Ecol. 27: 287–334.

NIEMUTH, W., W. CHURCHILL, and T. WIRTH. 1959. The walleye, its life history, ecology and management. Wis. Conserv. Dep. Publ. 227: 14 p.

RANEY, E. C., and E. A. LACHNER. 1942. Studies of the summer food, growth, and movements of young yellow pike-perch, *Stizostedion v. vitreum*, in Oneida Lake, New York. J. Wildlife Manage. 6: 1–16.

ROBINS, G. L. MS 1970. A bibliography of the pike perch of the genus *Stizostedion* (including the genus known as *Lucioperca*). Fish. Res. Board Can. Tech. Rep. 161: 67 p.

Pt. 2. Darters

ATZ, J. W. 1940. Reproductive behavior in the eastern johnny darter, *Boleosoma nigrum olmstedi* (Storer). Copeia 1940: 100–106.

BAILEY, R. M., and W. A. GOSLINE. 1955. Variation and systematic significance of vertebral counts in the American fishes of the family Percidae. Misc. Publ. Mus. Zool. Univ. Mich. 93: 44 p.

CARLANDER, K. D. 1941. The darters (Etheostominae) of Minnesota. Proc. Minn. Acad. Sci. 9: 41–48.

COLE, C. F. 1965. Additional evidence for separation of *Etheostoma olmstedi* Storer from *Etheostoma nigrum* Rafinesque. Copeia 1965: 8–13.

1967. A study of the eastern Johnny darter, *Etheostoma olmstedi* Storer (Teleostei, Percidae). Chesapeake Sci. 8: 28–51.

COLLETTE, B. B. 1963. The subfamilies, tribes, and genera of the Percidae (Teleostei). Copeia 1963: 615–623.

1965. Systematic significance of breeding tubercles in fishes of the family Percidae. Proc. U.S. Nat. Mus. 117(3518): 567–614.

1967. The taxonomic history of the darters (Percidae: Etheostomatini). Copeia 1967: 814–819.

FAHY, W. E. 1954. The life history of the northern greenside darter, *Etheostoma blennioides blennioides* Rafinesque. J. Elisha Mitchell Sci. Soc. 70: 139–205.

GOSLINE, W. A. 1947. Some meristic characters in a population of the fish *Poecilichthys exilis*: their variation and correlation. Occas. Pap. Mus. Zool. Univ. Mich. 500: 23 p. + 2 pl.

Karr, J. R. 1964. Age, growth, fecundity and food habits of fantail darters in Boone County, Iowa. Proc. Iowa Acad. Sci. 71: 274–280.

Knapp, L. W. MS 1964. Systematic studies of the rainbow darter, *Etheostoma caeruleum* (Storer), and the subgenus *Hadropterus* (Pisces, Percidae). Ph.D. Thesis. Cornell Univ., Ithaca, N.Y. 206 p.

Lake, C. T. 1936. The life history of the fan-tailed darter *Catonotus flabellaris flabellaris* (Rafinesque). Amer. Midland Natur. 17: 816–830.

Linder, A. D. 1959. The American percid fishes *Ammocrypta clara* Jordan and Meek and *Ammocrypta pellucida* (Baird). Southwest Natur. 176–184.

Miller, R. V. 1968. A systematic study of the greenside darter, *Etheostoma blennioides* Rafinesque (Pisces: Percidae). Copeia 1968: 1–40.

Morgan, G. D. 1936. A study of the vestigial air bladder in the darter *(Catonotis flabellaris* Rafinesque). J. Sci. Lab. Denison Univ. 31: 143–158 + pl. 59–68.

Petravicz, J. J. 1936. The breeding habits of the least darter *Microperca punctulata* Putnam. Copeia 1936: 77–82.

Petravicz, W. P. 1938. The breeding habits of the black-sided darter, *Hadropterus maculatus* Girard. Copeia 1938: 40–44.

Raney, E. C., and E. A. Lachner. 1943. Age and growth of johnny darters, *Boleosoma nigrum olmstedi* (Storer) and *Boleosoma longimanum* (Jordan). Amer. Midland Natur. 29: 229–238.

Reeves, C. D. 1907. The breeding habits of the rainbow darter (*Etheostoma coeruleum* Storer), a study in sexual selection. Biol. Bull. (Woods Hole) 14: 35–59.

Seifert, M. F. 1963. Some aspects of territorial behavior of the fantail darter. Proc. Iowa Acad. Sci. 70: 224–227.

Turner, C. L. 1921. Food of the common Ohio darters. Ohio J. Sci. 22: 41–62.

Underhill, J. C. 1963. Distribution in Minnesota of the subspecies of the percid fish *Etheostoma nigrum*, and of their intergrades. Amer. Midland Natur. 70: 470–478.

Winn, H. E. 1953. Breeding habits of the percid fish *Hadropterus copelandi* in Michigan. Copeia 1953: 26–30.

1958a. Comparative reproductive behavior and ecology of fourteen species of darters (Pisces–Percidae). Ecol. Monogr. 28: 155–191.

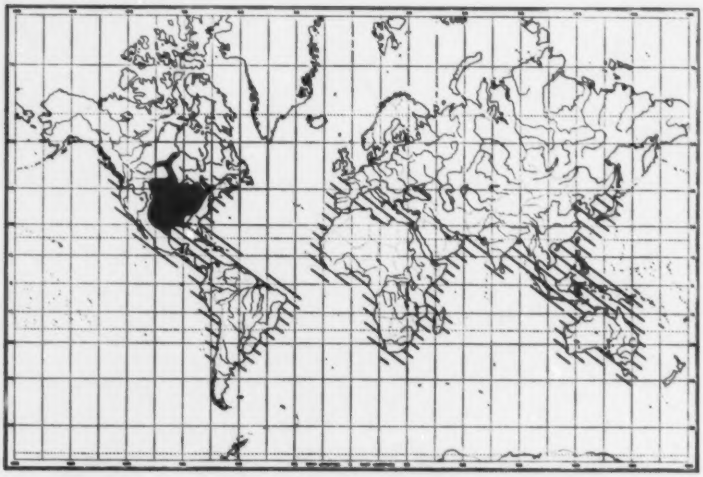
1958b. Observations on the reproductive habits of darters (Pisces–Percidae). Amer. Midland Natur. 59: 190–212.

DRUM OR CROAKER FAMILY — Sciaenidae

A well-defined family of heavy-bodied fishes, many species compressed laterally. Skull strongly ossified and characterized by struts and cavities that are adaptations for the mucous glands of the lateral line system; jaws armed with conical or lanceolate teeth; lower pharyngeal arches sometimes fused, but armed with buttonlike, crushing teeth; the main (sagitta) otolith is well developed, large, and heavy. Branchiostegal rays 7. Spiny and soft dorsal fins distinct, only slightly connected at base; anal fin with 2 spines joined to soft rays. Scales ctenoid, on head and body; lateral line well developed and extended throughout length of caudal fin.

The drums are widely distributed on continental shelves of tropical to temperate seas throughout the world. The species range in size from a few inches to over 200 pounds, and many are important food fishes. The names drum or croaker refer to their ability to produce sounds using the swim bladder as a resonating chamber.

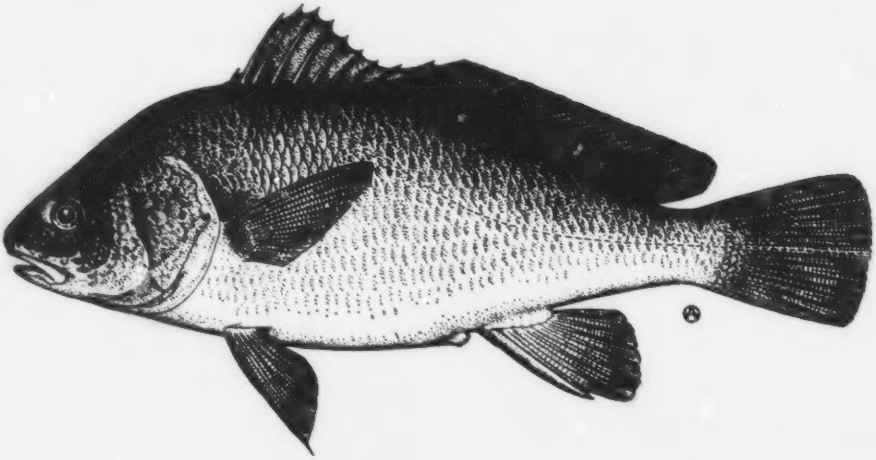
The family contains about 160 species, only 1 of which occurs in Canadian fresh waters. Paleocene to Recent.



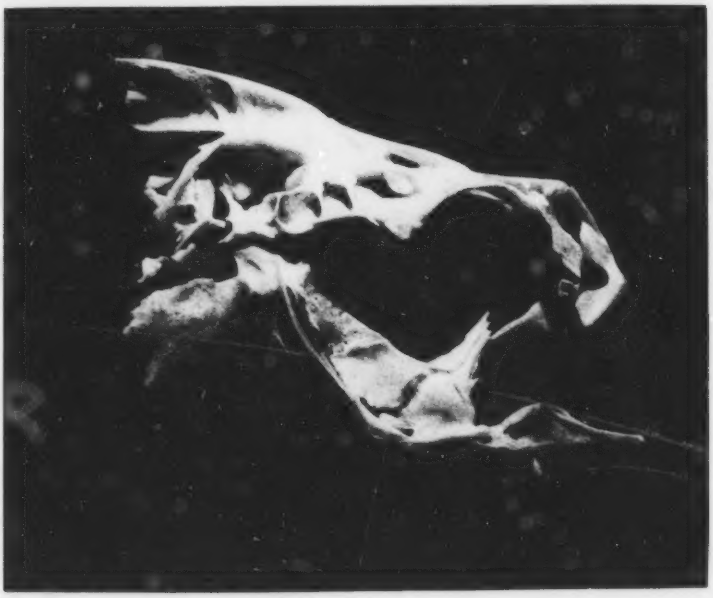
World Distribution of the Drums

FRESHWATER DRUM

Aplodinotus grunniens Rafinesque



Description Body compressed laterally, deepest immediately in front of dorsal fin, its depth 21.5–28.7% of total length, average length to about 18–20 inches (457–508 mm), the anterior dorsal outline with a steep arc to the dorsal fin. Head bluntly triangular, its length 21.3–22.7% of body length, skull quite distinctive among our freshwater fishes, with many cavities and strutted supports (*see* accompanying photo);



interorbital 23.8–28.0% of head length; eye relatively small, horizontal diameter 20.8–30.4% of head length; snout blunt 23.4–28.8% of head length; maxillary slender, extending to anterior edge of eye; mouth small, and overhung by blunt snout, gape terminating in front of eye, teeth in jaws slender and in many rows; pharyngeal teeth well developed, heavy, and armed with small, rounded, crushing teeth (*see* p. 25). Gill rakers 15(14–16) + 8(7–9). Branchiostegal rays 7. Fins: dorsals 2, the first spiny and connected to the second soft-rayed fin by a narrow membrane but the 2 separated by a distinct notch; first dorsal short, 8 or 9 spines, the third spine usually longest, second dorsal long, extended to caudal peduncle, of 1 spine and 25–33 (30–32, Lake Abitibi) branched rays; caudal rounded; anal of 2 spines, the second greatly enlarged, and 7 branched rays; pelvics thoracic, of 1 spine and 5 branched rays, the first branched ray prolonged into a distinct whitish filament; pectorals inserted in advance of pelvic fins, somewhat pointed, usually 17 branched rays. Scales ctenoid, large, growth lines readily visible with magnification, covering head and body and extending to base of soft dorsal fin, pored scales in lateral line 48–53 (to anterior margin of hypural plate), but pores extend in median line along length of caudal fin. Vertebrae 24.

Certain skeletal features of this species are uniquely characteristic among Canadian freshwater fishes, especially the fused pharyngeal arches with their teeth, the large saccular otoliths (*see* accompanying photo), the greatly enlarged second anal spine and the peculiarly strutted skull.

Colour Overall colouration silvery, back dark green to olive brown, sides silvery and the belly usually white. The pelvic fins are white to cream in colour, pectoral fins clear and remaining fins dusky.

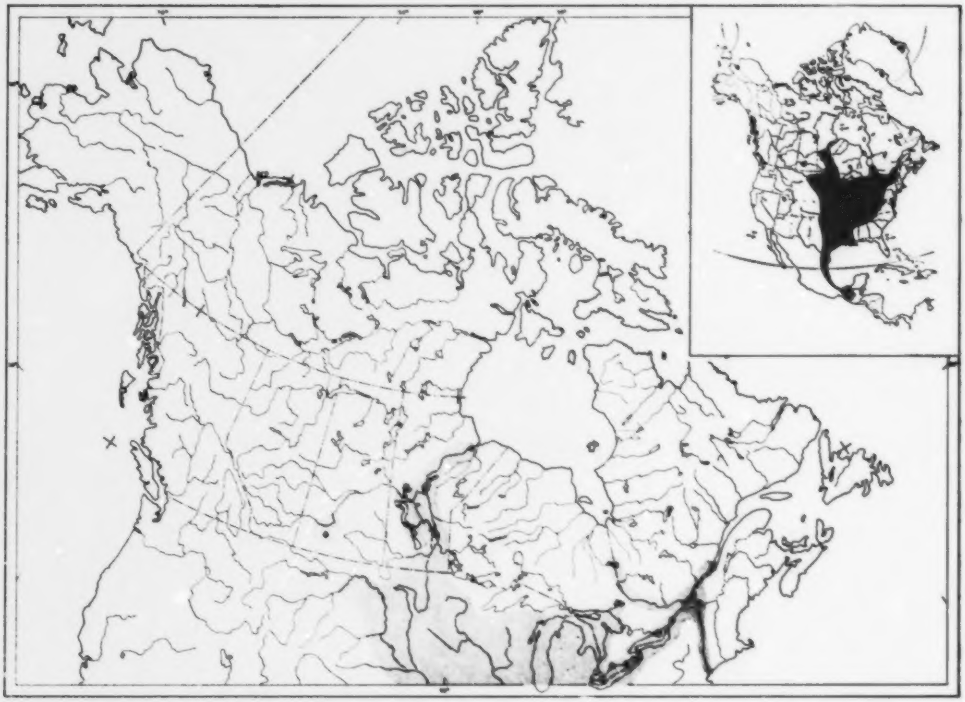
Systematic notes Krumholz and Cavanah (1968) concluded that this species displays remarkable stability in meristic values. Their critical study involved specimens from Kentucky and Wisconsin. Specimens from the northern limits of range have not been critically appraised, although Dymond and Hart (1927) presented morphometric and meristic data for specimens from Lake Abitibi, Ont. It should be noted that although meristic values are stable, rates of growth vary greatly throughout the range.

Distribution The freshwater drum is generally distributed throughout the Mississippi drainage basin, from Pennsylvania to Montana and Nebraska, south to the Gulf states, eastern Mexico, to the Rio Usumacinta system in Guatemala. It is found also in Lake Champlain.

In Canada the species occurs in the upper St. Lawrence River, Ottawa River, north to Lake Abitibi, and in the Great Lakes, except Lake Superior. Common in Lake Erie. It is found in the Hudson Bay drainage of Manitoba, and southwestern Saskatchewan, and reaches the northern limit of its range in the Nelson River in Manitoba (Scott and Kooyman 1952).

Biology It is strange that the spawning or breeding behaviour of the freshwater drum has not been documented, particularly since the species is credited with having the greatest latitudinal range of any North American freshwater species. Yet in the northern part of its range at least this appears to be the case.

Many aspects of the life history of the drum in Lake Erie have been investigated. One such study (Daiber 1953) indicated that spawning in the western basin probably occurred in



July although recently spent females were taken as late as September 11. Daiber used ovary weight: body weight ratios to determine time of spawning. He did not observe spawning and was unable to produce conclusive evidence to indicate where it occurred, but, on the basis of collections of young fish, concluded that spawning may have occurred in bays and lower portions of rivers and in the open lake, possibly over a bottom of sand and mud and to a depth of about 6 feet. The characteristic drumming sounds, made by the action of muscles connected to the swim bladder, are heard more frequently during the summer and may be a component part of the spawning ritual. The fish owes its name to this sound-producing ability.

Daiber calculated the number of eggs in the ovaries of nine females. The extreme ranges in egg number were 43,000–508,000 eggs but the remaining seven ovaries ranged from 209,000 to 341,000 eggs. Extruded eggs measured 1.15–1.7 mm in diameter, had a large oil globule 0.64–0.72 mm in diameter, and are unique among North American fishes since the egg is buoyant and floats right at the surface. Hatching takes place probably in about 25–30 hours at a temperature of about 71.6° F (22° C). *See* Davis (1959) for further details of this planktonic egg. As Davis has remarked, it seems extraordinary considering the abundance of freshwater drum in Lake Erie, that the egg was not observed and described prior to 1959. The evidence was available but apparently not appreciated, for Langlois (1954) reported observations made on three specimens in the Toledo (Ohio) Aquarium that spawned every year and whose floating eggs were partially lost (50%) via the overflow. The floating egg, which can be carried by currents, is probably one of the more significant factors responsible for the extremely wide range of the drum, but *see* Barney (1926) for a thorough but dated discussion of distribution.

Lake Erie populations exhibit a rapid

rate of growth in the first year but the rate in subsequent years is slower than for populations in more southern waters. It must be assumed that rates of growth for populations in such Canadian lakes as Nipissing, Winnipeg, and Abitibi are even slower than for those in Lake Erie. The following figures are total lengths and the weights for males and females at the end of each year of life for Lake Erie populations (modified from Edsall 1967):

Year of life	Length		Wt (*oz*)	
	(*inches*)	(*mm*)	Males	Females
1	5.1	130	0.8	0.9
2	7.9	201	3.3	3.3
3	10.1	257	7.0	6.7
4	11.5	292	10.2	10.2
5	13.0	330	12.7	13.7
6	13.9	353	15.2	17.5
7	15.3	388	17.5	20.6
8	16.0	406	20.2	24.0
9	16.7	424	23.0	28.4
10	17.6	447	25.6	33.2
11	–	–	28.4	37.9
12	–	–	32.0	40.8

After the sixth or seventh year annual increments were small and hence fish must live to an advanced age in order to reach a large size. Various texts often contain statements suggesting that the drum formerly attained very large sizes, such as 100 or even 200 pounds. But Witt (1960) investigated sizes of drum in ancient times using otoliths found in Indian middens, some dating to 6000 B.C., and concluded that the maximum size for the species in earlier times was probably well under 100 pounds. Average sizes in Ontario waters of Lake Erie are about 1.5–3.0 pounds, but larger specimens are occasionally caught in other Canadian waters as follows: Ottawa River, 1959, to 7.5 pounds; Hay Bay, Lake Ontario, 1964, to 24 pounds (a Canadian record?); Lake Nipissing, at least to 17 pounds, and fish of about 10 pounds are not unusual; Lake Abitibi, to 14 pounds (Dymond and Hart 1927).

The drum is a resident of large, shallow bodies of water and although it apparently prefers clear water it can obviously adapt to relatively high turbidity levels. Little information is available on movements and depth preferences although available evidence suggests that it lives mostly in shallows, i.e., to 40–60 feet.

The freshwater drum is adapted to bottom feeding, as the position of its mouth suggests. Studies in Ohio, Wisconsin, and other United States waters indicate that young-of-the-year eat mostly zooplankton and chironomids; young drum (to 30 mm) eat entromostracans, but as they grow larger aquatic insects become increasingly important. Mayflies *(Hexagenia)* and amphipods *(Gammarus)* are important food items at all sizes. As drum grow larger, fish and crayfish appear more frequently in the diet. Daiber (1952) recorded darters and lake emerald shiner in stomachs of Lake Erie specimens. Although molluscs such as snails and clams are natural foods, they appear to be more important in the diet of river-dwelling than of lake-dwelling populations. The large fused pharyngeal arches are particularly well adapted for crushing mollusc shells.

The freshwater drum appears to have few natural enemies, except during the vulnerable young-of-the-year stage. The covering of heavy ctenoid scales affords considerable protection for Great Lakes populations against attack by sea lamprey.

Bangham and Hunter (1939) considered that the freshwater drum in Lake Erie displayed an unusually high degree of parasitic infestation since all but 4 of 48 individuals examined showed varying degrees of infestation by an unusually diversified list of parasite species. Among the forms identified were trematodes, cestodes, nematodes, acanthocephalans, and myxosporidians. *See* Bangham and Hunter (1939) for further details. *See also* Hoffman (1967) for list of parasites of this species in North American waters.

Relation to man The freshwater drum is a commercial rather than a sport fish although it is taken incidentally by anglers fishing for other species. The Canadian commercial catch has exceeded 1 million pounds (Ontario, in 1966, landed over 1 million pounds) of which about 75% is caught in Lake Erie, and smaller quantities in Lake

Winnipeg and Lake Ontario (Bay of Quinte). The total annual catch from the Great Lakes (United States and Canada) fluctuates from 3 to 5 million. The Lake Winnipeg yield is utilized largely as mink food, and is considered highly desirable for this purpose.

Although Canadian anglers are prone to scorn this fish, it does put up a good fight when hooked, and grows to a large size, therefore warranting greater exploitation by anglers. As proof, perhaps, of its game qualities it has successfully masqueraded as a smallmouth bass! In 1964 a freshwater drum, weighing 11 pounds, 8 ounces, was entered in a big fish contest in Ontario as a smallmouth bass, and due to a misunderstanding and misidentification, won the contest. This erroneous record is still listed (1970) as a record smallmouth bass.

The edibility of the freshwater drum seems to vary from lake to lake, and small fish of 1–2 pounds are usually more palatable than large fish. The flesh is white, with large coarse flakes. In the central part of its range, it is sometimes marketed as "white perch."

Nomenclature

Aplodinotus grunniens — Rafinesque 1819: 418 (type locality Ohio River)
Sciaena oscula — LeSueur 1822b: 252
Sciaena (Corvina) oscula (LeSueur) — Richardson 1836: 68
Corvina Richardsonii — Forelle 1857: 280
Corvina oscula DeKay — Bean 1903b: 590

Etymology *Aplodinotus* — simple or single; back; *grunniens* — grunting.

Common names Freshwater drum, sheepshead, drum, sunfish, silver bass, Red River bass, grunter, "gray bass," "white perch." French common name: *malachigan.*

Suggested Reading — Sciaenidae

BARNEY, R. L. 1926. The distribution of the fresh-water sheepshead, *Aplodinotus grunniens* Rafinesque, in respect to the glacial history of North America. Ecology 7: 351–364.

DAIBER, F. C. 1952. The food and feeding relationships of the freshwater drum, *Aplodinotus grunniens* Rafinesque in western Lake Erie. Ohio J. Sci. 52: 35–46.

1953. Notes on the spawning population of the freshwater drum (*Aplodinotus grunniens* Rafinesque) in western Lake Erie. Amer. Midland Natur. 50: 159–171.

EDSALL, T. A. 1967. Biology of the freshwater drum in western Lake Erie. Ohio J. Sci. 67: 321–340.

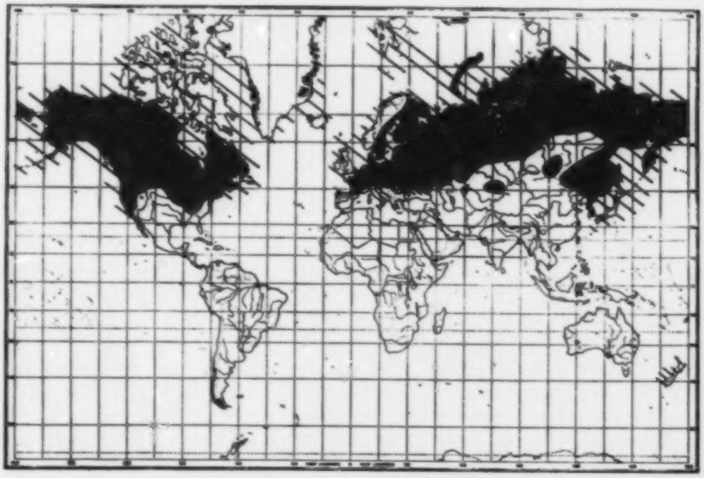
KRUMHOLZ, L. A., and H. S. CAVANAH. 1968. Comparative morphometry of freshwater drum from two midwestern localities. Trans. Amer. Fish. Soc. 97: 429–441.

SCULPIN FAMILY — Cottidae

The sculpins form a distinctive group of perciform-like fishes although the ordinal relationships of related families are not clear. For convenience, we have chosen to include the sculpins in the order Perciformes. The sculpins form a rather distinctive group of fishes and many of the morphological features reflect the bottom-living habits which are so characteristic of the group. Sculpins are large-headed and heavy-bodied fishes, the body tapers from the head to a relatively narrow caudal peduncle; skull low, generally broad, composed usually of thin bones; the preopercular bone often variously armed with spines; the second suborbital prolonged posteriorly to form a narrow, bony plate across the cheek, usually articulating with preoperculum; eyes dorsal in position, prominent; jaws strong, teeth well developed, premaxillae toothed and forming border of upper jaw; post-temporal not enlarged. Branchiostegal rays 5–7. Fins with spines; dorsal fins usually 2, usually narrowly divided, first dorsal spiny, second dorsal soft rayed; 1 anal fin without spines; pelvics in advanced thoracic position, of 1 spine and 4, 3, or 2 soft rays; pectoral fins large and fanlike. Scales ctenoid type but usually reduced and tuberculate and reduced to lateral line or scattered rows on body, body not normally covered with overlapping scales; lateral line variously developed. Vertebrae 23–50.

The sculpins are bottom living, primarily marine fishes, of arctic and temperate seas but 1 genus in particular, *Cottus*, is widely distributed in fresh waters of the northern hemisphere.

Although small fishes of 7 inches or less in fresh water, some marine species may attain lengths of 24 inches or more. The family contains at least 300 species of which 8 occur in Canadian fresh waters. Oligocene to Recent.

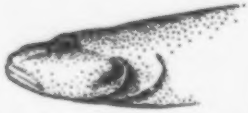


World Distribution of the Sculpins

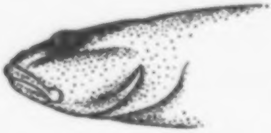
Key to Species

1 Margin of gill membrane free from isthmus (*see* couplet 14, p. 31) second preopercular spine directed backwards, conspicuous; dorsal fins separated by a distinct gap. .... DEEPWATER SCULPIN, *Myoxocephalus quadricornis* (p. 842)

Margin of gill membrane attached to isthmus; second preopercular spine skin covered, and directed downwards; dorsal fins touching or narrowly joined. 2



2 Lateral line complete to base of caudal without deflection; upper preopercular spine usually longer than two-thirds eye diameter and curved strongly upward; mandibular pores large, 1 mandibular pore on midline at tip of chin. .... SPOONHEAD SCULPIN, *Cottus ricei* (p. 839)



Lateral line incomplete, or if complete, deflected downwards on caudal peduncle; upper preopercular spine equal to one-half eye diameter and curved gently upward; 1 or 2 mandibular pores on midline at tip of chin. 3

3 Two pores on tip of chin; lateral line complete or incomplete; first 2 dorsal spines not noticeably close together (associated with separate basals); caudal vertebrae 20–24. 4

One pore on tip of chin; lateral line complete; first 2 dorsal spines noticeably close together (associated with single basal); caudal vertebrae 24–28. 7

4 Lateral line complete; palatine tooth patch long, and in contact with vomerine tooth patch; head length 3 times or less in standard length; prickles on body usually extending onto sides and back, base of prickle serrate; usually 2 dark, narrow, forward-slanting bars under second dorsal fin. .... TORRENT SCULPIN, *Cottus rhotheus* (p. 837)

Lateral line incomplete; palatine tooth patch absent or short, not in contact with vomerine tooth patch; head length usually 3 times or more in standard length; prickles restricted to a small area behind pelvic fin, base of prickle not serrate; either 3 dark bars or none under second dorsal fin. 5

5 Palatine teeth absent; anal fin rays usually 10–12; pelvic fin rays 3 or 4, when present the fourth ray usually less than two-thirds length of longest pelvic ray; last 2 dorsal and anal rays often separated, arising from separate basals. .... SLIMY SCULPIN, *Cottus cognatus* (p. 830)

Palatine teeth present; anal fin rays usually 12–14; pelvic fin rays 4, the fourth about three-quarters length of the longest ray; last 2 dorsal and anal rays close together, arising from same basal. 6

6 Head length usually 2.9–3.2 in standard length; pectoral fin rays usually 14–16; lateral line incomplete and usually of 28–36 pores; preopercular spines 3. .... MOTTLED SCULPIN, *Cottus bairdi* (p. 826)

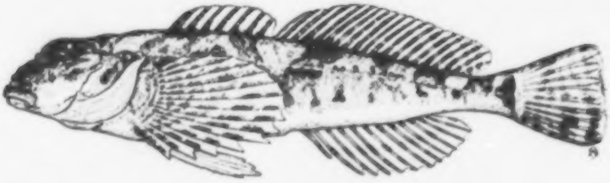
Head length usually 3.2–3.9 in standard length; pectoral fin rays usually 13 or 14; lateral line incomplete and usually of 22 to 33 pores; preopercular spines 2. .... SHORTHEAD SCULPIN, *Cottus confusus* (p. 835)

7 Anal fin rays 15–19; pectoral fin rays 15–18; palatine teeth present; dark, oval spot on upper posterior portion of first dorsal fin; posterior nostril not tubular. .... PRICKLY SCULPIN, *Cottus asper* (p. 823)

Anal fin rays 12–14 (rarely 15 or 16); pectoral fin rays 13–16; palatine teeth absent; dark, oval spot absent on first dorsal fin; posterior nostril tubular. .... COASTRANGE SCULPIN, *Cottus aleuticus* (p. 820)

COASTRANGE SCULPIN

Cottus aleuticus Gilbert



Description Body elongate, average total length 3–4 inches (76–102 mm), typically cottoid, heaviest forward, decreasing in size posteriorly to a moderately deep caudal peduncle, posterior portion noticeably compressed laterally. Head moderate, its length 24–30% of total length, maxillary extends posteriorly to below anterior edge of orbit, well-developed preopercular spine directed upward and backward, preoperculo-mandibular pore count 10–1–10, one pore on tip of chin; eye small; mouth moderate; teeth well developed in upper and lower jaws, and vomer, but no teeth on palatines. Branchiostegal rays 6,6(4), 6,7(1). Fins: dorsals 2, the first with a short base, spiny with 8–10 spines, the second dorsal longer and higher than first, soft rayed, with 16–20 rays, 2 dorsals distinctly but narrowly separated; caudal slightly rounded; anal with long base, soft rayed, 12–16 rays but 15,16 rare; pelvics small, of 1 spine and 4 soft rays; pectorals moderately large and fanlike, 13–16 rays. Typical scales absent, small prickles restricted to a patch behind each pectoral fin; lateral line usually complete, deflecting to midline on the caudal peduncle with 34–44 pores. Vertebrae 34–38, caudal vertebrae 24–27.

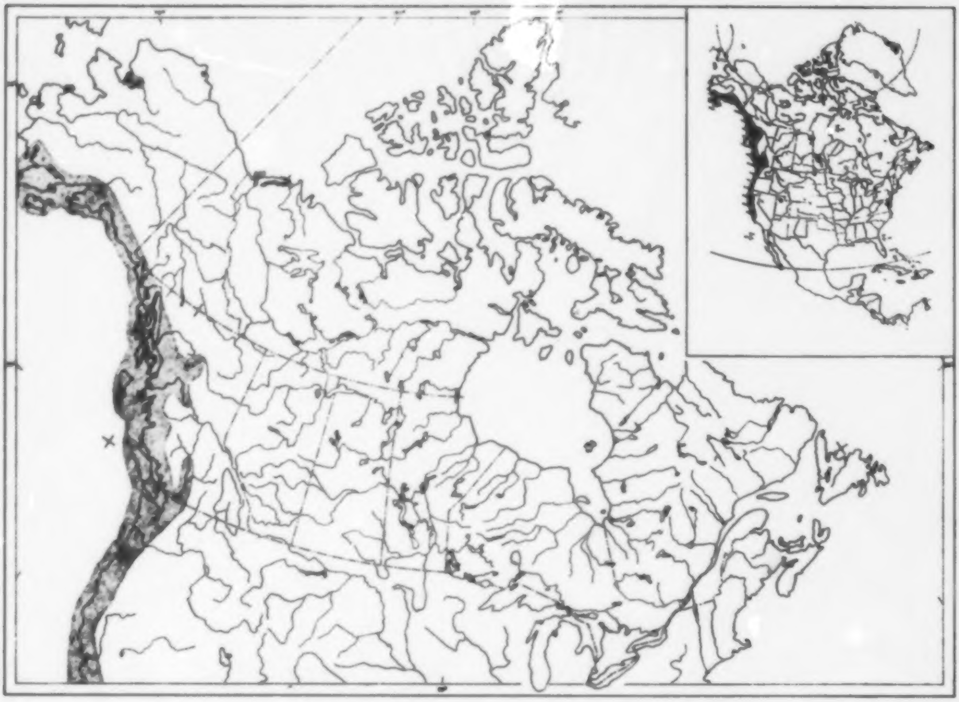
Colour Overall colouration brown or grey with darker blotches, lighter on sides and white below. Two or three dark, saddle-like marks usually developed under second dorsal fin. Pigment on dorsal, caudal, anal, and pectoral fins usually in form of bars. Chin evenly speckled. Sometimes there is a light patch or bar on caudal peduncle behind the soft dorsal. Young fish may not have pigmentation on fins. Spawning males are generally darker overall, and have an orange band on edge of the first dorsal fin.

Systematic notes The original description by Lockington (1880) as *Uranidea microstoma* and the subsequent redescription by Gilbert was reviewed by Robins and Miller (1957). These authors also re-examined the form described by Schultz and Spoor (1933) as *Cottus protrusus*, so-named because of its protruding eyes, and reduced *C. protrusus* to the synonymy of *C. aleuticus*.

Ricker (1960) documented a population of dwarf coastrange sculpins dwelling, throughout their lives, in the deeper waters of Cultus Lake, B.C.

Geographic variation was discussed by McAllister and Lindsey (1961) who considered only pectoral rays to vary significantly between coastal and inland populations, and by McPhail and Lindsey (1970), who remarked upon the difference in anal ray counts of British Columbia specimens (usually 14 rays) compared with Bristol Bay, Alaska, specimens (usually 12 or 13 anal rays). The latter authors also discussed the postglacial dispersal of the species in the northern part of its range.

Distribution The coastrange sculpin occurs from San Luis Obispo County, Calif.,



northward, mainly in coastal streams, along the west coast of North America to Kiska Island, near the western extremity of Alaska's Aleutian Islands. An isolated population occurs in the Kobuk River, just north of the Arctic Circle, in the Chukchi Sea drainage, 500 miles north of the Bristol Bay population of southern Alaska.

In Canada, it occurs in coastal streams and nearby inland lakes from the Fraser River and its tributaries as far upstream as Lillooet, north in such rivers as the Skeena, Nass, and Stikine, and on Vancouver and Queen Charlotte islands.

Biology The coastrange sculpin spawns in streams in spring, probably between February and mid-June. The orange-coloured adhesive eggs, less than 1.5 mm in diameter, are deposited on the undersurface of a rock, in adhesive masses, and are guarded by the male. Over 7000 eggs in different stages of development have been observed in a single nest and it is assumed that a male may spawn with more than one female. A large female may deposit as many as 800 eggs.

A deep-dwelling lake population of coastrange sculpins from Cultus Lake was described by Ricker (1960), who estimated that spawning occurred from late May or early June to August and even September.

On hatching, the young become planktonic in the stream estuary or in lakes and do not take up a bottom-dwelling or benthic life until about 32–35 days after hatching. The movement and fate of planktonic coastrange sculpins was discussed by Heard (1965) and McLarney (1968).

The preference for a flowing water environment develops after they become bottom living.

As noted by McPhail and Lindsey (1970) growth data for Canadian populations is minimal but a maximum age of 4 years was reported for Oregon. Ricker (1960) discussed the possible age structure of a deepwater population but the ages used were approximations based on size groups. The maximum size is apparently about 4.5 inches (115 mm) according to figures presented by Ricker.

The coastrange sculpin characteristically occurs in the fast water of coastal streams and rivers, usually on a gravel bottom. It may also move downstream to estuaries and is tolerant of brackish water. It also occurs in inshore, quiet waters of lakes, over sandy or muddy bottoms. The population of unusually small *aleuticus* (maximum length about 50 mm) described by Ricker (1960) apparently spends its entire life (except as limnetic larvae?) living in the deeper waters of Cultus Lake, not entering the shore waters even to spawn. An unusual aggregation in an Alaskan lake was described by Greenbank (1957) who observed 100–125 fish clustered on a single large boulder, 2 or 3 fish deep.

The food of this sculpin varies with the habitat and time of year. McPhail and Lindsey (1970) noted that feeding usually occurs at night. Aquatic insects and other benthic invertebrates, especially molluscs, are principal foods but in autumn salmon eggs may be eaten extensively. *Daphnia*, chironomid larvae, and ostracods were eaten by the Cultus Lake deepwater sculpins and one had consumed a smaller *aleuticus*, 14 mm long. Consumption of eggs and fry of salmon, particularly those of pink salmon, was noted by Pritchard (1936). Predation on salmon in general in California waters was discussed by Shapovalov and Taft (1954).

The effect of predation by sculpins upon production of pink and chum salmon was discussed by Hunter (1959), although his results probably apply mostly to the prickly rather than the coastrange sculpin. He calculated an average of about two salmon fry per cottid stomach.

The complexity of predator–prey relations was emphasized by Heard (1965) in a paper describing the feeding by young sockeye salmon upon the planktonic larvae of *C. aleuticus*. Most reported predation involving cottids and salmonids concerned consumption of salmon by cottids.

Coastrange sculpins are also eaten by other fishes, such as coho salmon, cutthroat trout, and Dolly Varden char. Ricker (1960) reported as many as 100 sculpins in a single char stomach.

Hoffman (1967) listed only two parasites from the coastrange sculpin, the protozoans *Cryptobia lynchi* and *C. salmositica*. McAllister and Lindsey (1961) noted that the tubercles reported to occur on the pelvic fins of some Alaskan specimens by Evermann and Goldsborough (1907b) on re-examination were shown to be encysted parasites. There are no other reports of parasites in this sculpin in Canadian literature.

Relation to man The coastrange sculpin, although not used directly by man, serves as a forage fish for some valued salmonids, but in turn feeds upon the eggs and larvae of some species of salmon. As in the case of *Cottus asper*, this species is probably of most interest because of its complex but poorly understood food relations with the salmons (*Oncorhynchus* spp.).

Nomenclature

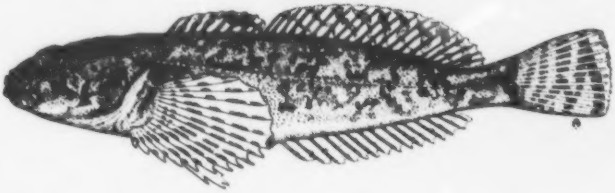
Cottus aleuticus sp. nov. — Gilbert 1895: 418 (type locality streams of Unalaska, Alaska)
Uranidea microstoma — Lockington 1880: 58 (name preoccupied)
Cottus protrusus n.sp. — Schultz and Spoor 1933: 142

Etymology *Cottus* — an old European name; *aleuticus* — of the Aleutians.

Common names Coastrange sculpin, Aleutian sculpin. French common name: *chabot côtier*.

PRICKLY SCULPIN

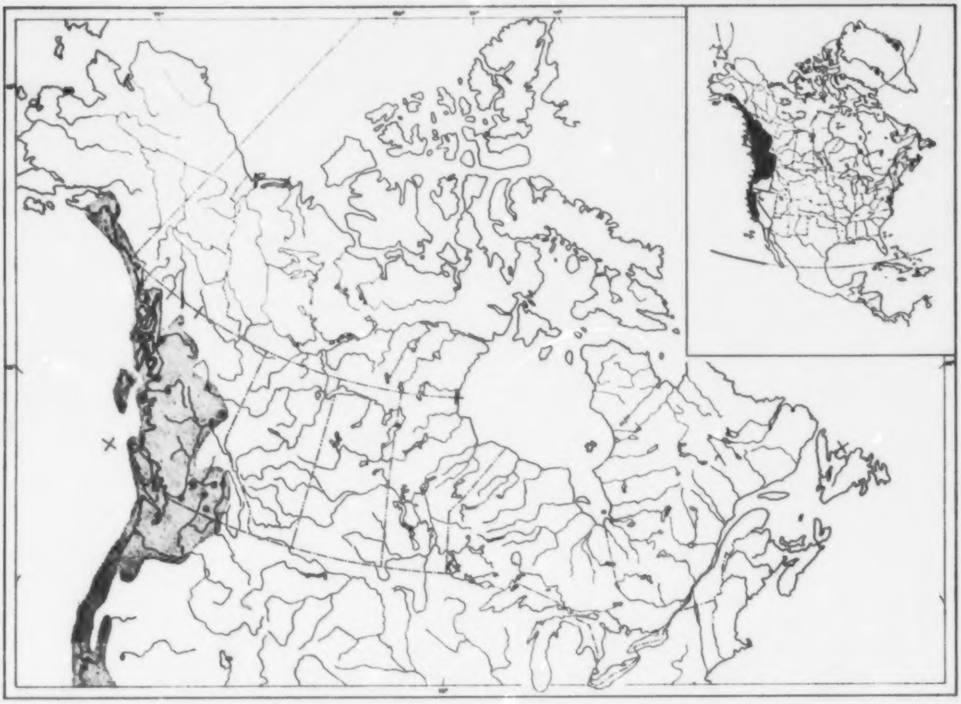
Cottus asper Richardson



Description Body typically cottoid, heaviest forward, decreasing in size posteriorly, compressed laterally from about the junction of the 2 dorsal fins to the obviously compressed caudal peduncle. Head large, its length 25.5–31.8% of total length, maxillary extends posteriorly to middle of eye or beyond in adults, large preopercular spine directed posteriorly, 1 or 2 below it pointing downwards, preoperculo-mandibular pores 10–1–10, with a single pore on chin tip; gill membranes joined to isthmus although superficially may appear to be free from isthmus; eye relatively large, its diameter 18.0–33.3% of head length; mouth large (*see* Northcote 1954, for comparative measurements); teeth well developed on upper and lower jaws, strong on palatine and vomer, the latter tooth patches not in contact. Branchiostegal rays usually 6,6(14), but sometimes 6,5(1), 7,6(3), 7,7(1). Fins: dorsals 2, the first with short base, spiny, 8(17), 9(12), or 10(1) spines (McAllister and Lindsey 1961, gave range of 7–11), second dorsal longer and higher than first, soft rayed, rays 18(1), 19(4), 20(13), 21(9), 22(1), first and second fins lightly joined at base and separated by a distinct notch; caudal slightly rounded; anal with long base, soft rayed, rays 14(2), 15(1), 16(14), 17(9), 18(2); pelvics with 1 spine and usually 4 soft rays (may be 3 or 5); pectorals large, fanlike, with 15–18 rays. Typical scales absent but prickles may occur over whole body (except abdomen) or be restricted to axil of pectoral fin; lateral line usually complete, with 32–43 pores, sometimes a few missing on caudal peduncle. Vertebrae 34(2), 35(4), 36(4), caudal vertebrae 24–28.

Colour Olive to dark brown or grey overall above and on sides, becoming yellowish white or white below; usually with three dark bands under the second dorsal and the sides with vague black mottling. Chin usually lightly pigmented. Dorsals, caudal, anal, and pectoral fins usually barred (except on very young) and first dorsal fin with a distinct black oval mark posteriorly. Spawning males dark; both sexes have a thin orange band on edge of first dorsal at spawning time.

Systematic notes The early nomenclature is confused and misleading in part because of misidentification but due also to the variability exhibited by this sculpin. The nomenclature was thoroughly reviewed by Krejsa (1967a) but *see also* Robins and Miller (1957) and McPhail and Lindsey (1970). The geographic variation exhibited by the degree of prickle development on the body and also by such meristic characters as fin rays and vertebrae was presented by McAllister and Lindsey (1961). In general, inland populations are more densely prickled over a higher percentage of the body than are coastal populations. McPhail and Lindsey noted that Krejsa had evidence that suggested the two forms, coastal and inland, are genetically distinct, but that the coastal form had penetrated further inland in the northern part of the range.



Distribution The prickly sculpin ranges along the Pacific slope of North America from Seward, Alaska, south to Ventura River, Calif.

In Canada, it occurs in numerous coastal rivers, and widely in lakes and rivers of the Stikine, Nass, Skeena, Dean, Fraser, and Columbia River systems; on Queen Charlotte and Vancouver islands. East of the Continental Divide it is reported only in the upper Peace River (Mackenzie River system). For additional details on distribution, *see* Krejsa (1967a) and McPhail and Lindsey (1970).

Biology A detailed study of the life history of the prickly sculpin in British Columbia was published by Krejsa (1967a, b). The following information is derived largely from his work.

Spawning occurs usually in spring, and may be as early as February in the California part of its range. In British Columbia spawning usually takes place from about mid-March to as late as July 22 on Queen Charlotte Islands. Inland populations usually spawn later than coastal ones. Freshwater spawning is usual but coastal populations may spawn in brackish water. A downstream migration is usually associated with prespawning behaviour of coastal populations.

Streams having a boulder, cobble, and flat rock bottom, and a current flow of about 1 cubic foot per second, seem to be preferred. Males move onto spawning grounds before females and select a nesting site under a boulder or flat rock, preferably with a rough under surface. Females remain upstream until ready to spawn, when they move onto the spawning grounds and, following courting behaviour outside the nest, a female selected by a male enters the nesting site. Further courtship under the rock precedes deposition and fertilization of a jelly-enclosed cluster of 700–4000 eggs on the ceiling of the spawning chamber. After spawning, the spent females leave the nest. Males may spawn with as many as 10 females, each egg mass discernible and in a different stage of development, until many thousands of eggs are deposited (Krejsa 1967b, counted 25,000–30,000 in one nest). The eggs are less than 1 mm in diameter, orange in colour and adhesive. The males guard the eggs and fan them with alternating strokes of their pectoral fins. Laboratory studies indicated that they hatched in 15–16 days at a temperature of 53.6° F (12° C), when the larvae were 5–7 mm total length. They begin swimming at once and may form schools (Northcote and Hartman 1959) but remain pelagic for 30–35 days before metamorphosing and settling on bottom.

McPhail and Lindsey (1970) have already noted the absence of any growth data from the Canadian area but noted that a maximum age of 7 years has been recorded from Oregon. The maximum-sized female noted by Krejsa (1967b) was 7 inches (192 mm) standard length, but Carl et al. (1967) gave a possibly dubious overall maximum size of up to 12 inches (305 mm).

The prickly sculpin lives in coastal and inland streams, may occur along lake shores, and is also tolerant of salt water. It is usually an inhabitant of quiet waters and avoids strong currents. It is usually more active at night.

Aquatic insect larvae, especially chironomid and trichopteran larvae, and other bottom invertebrates, such as molluscs, apparently form the major food supply. Planktonic crustaceans are an important component in the diet of young up to 29 mm (Northcote 1954) but even at this stage aquatic insect larvae form the major part. Over 70 mm long, fish become increasingly important. Larger sculpins may consume a variety of items, such as fish eggs, and young of their own as well as of other species such as sockeye salmon (Ricker 1941; Robertson 1949).

A number of species have been reported to prey on prickly sculpins, including lake trout, Dolly Varden, lake whitefish, squawfish, and American mergansers (Munro and Clemens 1936).

Bangham and Adams (1954) examined 344 specimens from 25 locations in British Columbia and found 275 infected. They provided a detailed list of the parasites identified and noted that over half of the parasites reported were from a few fish taken in just one or two of the 25 locations surveyed.

Hoffman (1967) listed trematodes (2), cestodes (5), nematodes (4), acanthocephalans (1), molluscs (1), crustaceans (2).

Relation to man The importance of species with such a wide range, that occur in considerable numbers, is difficult to assess. It is not used directly but may be of considerable importance as food of, or predator on, other species.

Pritchard (1936), Munro and Clemens (1937), and Hunter (1959) presented data indicating that it did prey on the eggs and young of salmon (*Oncorhynchus* spp.) and rainbow trout. It is probably a significant predator upon the former although the full effect of such feeding activities is not known. Anglers, using worms or roe as bait, not infrequently catch prickly sculpins.

Its role in trout and salmon production in California has been discussed by Shapovalov and Taft (1954) who also suggested control methods.

Nomenclature

Cottus asper — Richardson 1836: 295 (type locality Columbia River, probably at Fort Vancouver, Washington Territory)
Trachidermus richardsonii — Heckel 1840: 162
Cottopsis asper — Girard 1852: 61
Cottopsis parvus, G. — Girard 1856c: 144
Centridermichthys asper — Lord 1866a: 130

Centridermichthys parvus — Lord 1866b: 352
Centridermichthys gulosus — Lord 1866b: 352

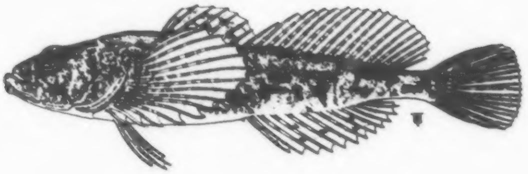
(*see* Krejsa 1967a, for complete synonymy)

Etymology *Cottus* — an old European name; *asper* — rough.

Common names Prickly sculpin, prickly bullhead, bullhead. French common name: *chabot piquant*.

MOTTLED SCULPIN

Cottus bairdi Girard



Description Body of characteristic cottoid shape with flattened and laterally expanded head, average total length around 3 inches (76 mm), body depth about equal to body width anteriorly, but posterior portion strongly compressed laterally, the caudal peduncle of moderate depth. Head flattened dorsoventrally and expanded posteriorly, the eyes on top of head, head length 22.2–28.9% of total length, maxillary extends posteriorly to below eye, large preopercular spine directed upward and posteriorly, 2 small spines directed downward, all covered by skin; gill membranes broadly joined to isthmus, operculo-mandibular pores 10–10 or 11–11 (2 on tip of chin); eye relatively large, its diameter 20.6–37.5% of head length; snout moderate, rounded in dorsal view; mouth moderate, upper lip protruding beyond lower; fine teeth developed on upper and lower jaws, on palatines and on vomer, vomer tooth patch separated from palatines. Branchiostegal rays 6,6(70), 5,5(1). Fins: dorsals 2, the first small, spiny, of 7(14), 8(52), or 9(2) spines, base short, the second with long base, soft rayed, 16(17), 17(37), 18(14) or 19 (McAllister 1964a) rays; caudal slightly rounded; anal with long base, soft rayed, 10(2), 11(3), 12(20), 13(36), or 14(7) rays, sometimes range 12–16 (McAllister 1964a); pelvics small, of 1 spine and 4(38), rarely 3(1), rays; pectorals large, fanlike, rays 13–17. Typical scales absent but small prickles present on patch behind pectoral fins, sometimes extending onto back; lateral line incomplete, terminating under posterior part of second dorsal fin. Vertebrae 31(7), 32(16), or 33(8), caudal vertebrae usually 21–23.

Colour Overall colouration light to dark brown with darker (sometimes almost black) mottling on back and sides, becoming light or even white below. Two, sometimes three, dark saddle marks may be evident under second dorsal fin. Chin usually irregularly speckled. The dorsal, caudal, anal, and pectoral fins marked with pigment, the first dorsal with spot fore and aft, which become continuous in breeding males to form a dark band with a broad orange distal edge, second dorsal spotted and banded, caudal more or less randomly speckled, anal usually darkly speckled, and pectorals banded.

Systematic notes The very considerable geographic variation exhibited by this species has given rise to a number of synonyms and to the recognition of a number of subspecies. The subspecies occurring in Canada were listed by Dymond (1947) based on Hubbs and Lagler (1941) as *C. bairdi bairdi*, the northern mottled sculpin, and *C. bairdi kumlieni*, the Great Lakes mottled sculpin. Additional subspecies have been described for populations in the southern United States.

Cottus bairdi and *Cottus cognatus* are closely related, both are members of the *bairdi* species group within the genus (Bailey and Bond 1963), and are exceedingly similar in most morphometric and meristic characters. In a study of the fishes of Isle Royale, Lake Superior, Hubbs and Lagler (1949) enumerated a number of characters considered most useful to distinguish *C. b. kumlieni* and *Cottus cognatus gracilis*. However, when specimens were compared from widely separated parts of Ontario and Quebec, McAllister (1964a) demonstrated that none of the characters previously enumerated or others listed in various keys would permit 100% separation of the two species, *C. bairdi* and *C. cognatus*, let alone two subspecies. The caudal peduncle length in *C. cognatus* always exceeded the distance from the eye to the bony edge of the operculum, while in *C. bairdi* it was always less than the postorbital length.

We suggest that the recognition of subspecies for *Cottus bairdi* populations in Canada implies a degree of detailed knowledge that has not yet been attained, since we know of no characters that will consistently permit separation of the described subspecies. A review of the literature treating the degree of variation observable in a single population of *Cottus bairdi*, such as that of Savage (1962), reinforces this viewpoint.

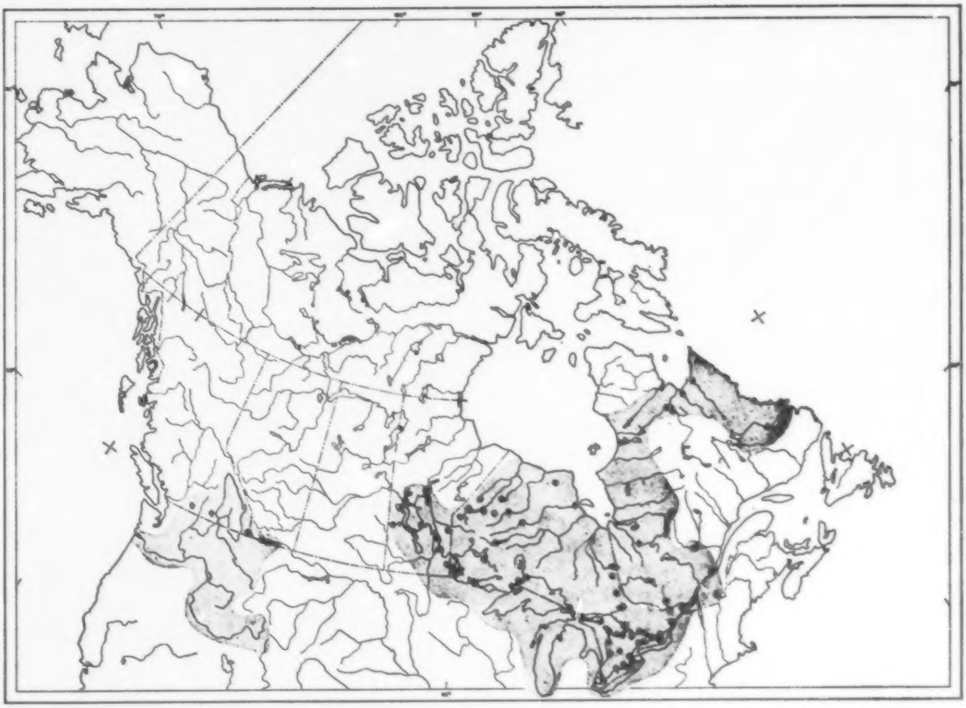
Distribution The mottled sculpin ranges widely but discontinuously through North America from at least the Tennessee River system of Georgia and Alabama to Labrador on the north, and west to the Great Lakes basin. From there, the distribution is discontinuous but includes parts of the Missouri River and the Columbia River systems, in southern Canada, Utah, Montana, Idaho, and Washington.

In Canada, the mottled sculpin occurs from the Lake Melville region of Labrador, Ungava Bay region of northern Quebec, west to Hudson Bay drainages; thence, through the intervening St. Lawrence–Great Lakes system and James and Hudson Bay drainages of almost all Ontario (except the extreme northwest), to southern Manitoba, including Lake Winnipeg and its tributaries, north at least to off the mouth of the Mukatawa River. The distribution becomes discontinuous west from Manitoba.

It occurs in the Milk River system of southern Alberta, and in the Similkameen River system and the Kettle River in southern British Columbia.

Biology There are few detailed observations on spawning activities or behaviour of the species in Canadian waters, but a number has been made in United States waters.

The mottled sculpin spawns in spring, but the exact date varies with geographic location. While engaged in field studies on brook trout on the Mad River, a branch of the Nottawasaga River, Ont., Ricker (1934) observed that spawning probably occurred about mid-May in 1930. Females with nearly ripe eggs were taken on May 3 and 10, but females were spent by June 14. On May 30, eyed eggs and small sculpins were found in brook trout stomachs. And, on July 3, young-of-the-year,



15 mm long, were abundant on a mud bottom at depths of 2–10 inches.

The spawning behaviour in general follows that of most members of the genus. The male becomes dark headed, selects a spawning or nesting site under a rock or ledge, the female enters the nest after suitable courting, deposits the adhesive eggs in a mass on the ceiling of the nest while upside down, and departs or is driven off. More than one female usually deposits eggs in the nest. The male remains to guard the eggs against predation and by alternately fanning his pectoral fins, maintains a current flow, or the nesting site is so positioned in flowing water that a natural current is maintained. Koster (1936) gave water temperature at time of spawning in upper New York State of 50° F (10° C). Koster suggested that hatching did not occur until about a month after deposition, but this would depend on temperature.

Details of behaviour during spawning, for populations in the United States, were given by Koster (1936), Bailey (1952), and Savage (1963).

Koster apparently successfully used otoliths to obtain ages of his specimens, and determined that spawning occurred at age 3, sometimes at age 2. Although the sexes are approximately equal in size, males are usually darker, have a larger head, and higher second dorsal and anal fins than females. A specimen from St. Ignace Island, Lake Superior, is the largest examined and measures 5.2 inches (132 mm) total length.

The mottled sculpin occurs in cool streams and lakes across Canada. In eastern Ontario, Toner (1943) noted that it was caught most often over a sand bottom in lakes and streams. In a study of the invertebrate and vertebrate fauna in southern Ontario streams, Hallam (1959) reported that the mottled sculpin was most often associated with the brook trout, *Salvelinus fontinalis*, a relation usually attributed to the slimy sculpin, *C. cognatus*. The average summer water temperature at stations where *C. bairdi* was caught, was given at 61.9° F (16.6° C). Hallam gave a description of the average *C. bairdi–S. fontinalis* habitat as follows: "Shaded source waters of low temperature and small volume of flow with many rapids." However, it does not usually occur as far up headwater streams nor as deep in lakes as *Cottus cognatus* (Deason 1939; Hubbs and Lagler 1949), which also has the more extensive northern range. However, Keleher (1952a) reported a specimen of *C. bairdi* taken in 54 feet of water in Lake Winnipeg. Its probable susceptibility to a sudden change in temperature was noted by Emery (1970) in Lake Huron, where a number were observed to have died following exposure to an underwater seiche which lowered the water temperature from 65.7° F (18.7° C) to 44.6° F (7° C) in a matter of seconds.

Like other members of the genus, the mottled sculpin is a benthic feeder subsisting mainly on aquatic insect larvae. Ricker (1934) examined stomach contents of 56 fish from the Mad River, Ont., and found chironomid larvae and mayfly nymphs to be most important in the diet of small sculpins under 2 inches (51 mm) long, but sculpins over 2 inches (51 mm) long ate fewer chironomids and more mayfly nymphs, especially nymphs of larger species. The larger fish supplemented their diet with stonefly nymphs, caddisfly larvae, and crayfish. Ricker noted that in this particular location, the sculpin's abundance and consumption of nymphs was probably responsible for the great reduction of mayflies of that species throughout the summer.

Food studies in United States waters show essentially the same feeding habits with emphasis on aquatic insect larvae and nymphs but crustaceans, annelids, fishes, fish eggs, and plant material may be consumed when available. Winter food habits in New York were studied by Daiber (1956) but differ little from those of summer.

A few cases have been reported of sculpins eating trout eggs (Greeley 1932; Koster 1937) but in fact they are not considered to be destructive of brook trout eggs, eating the odd egg that was improperly covered with gravel by spawning trout.

Sculpins are known to form a part of the diet of large brook trout, *S. fontinalis* (Ricker 1934), but seldom are *bairdi* differentiated from *cognatus* when removed from stomachs, hence it is not possible to evaluate the role of *C. bairdi* as food for trout. Utilization of lake-dwelling mottled sculpins is similarly poorly documented although it is undoubtedly eaten by smallmouth bass at times (Tester 1932a). Six specimens were reported eaten by water snakes, *Natrix sipedon*, in Lake Michigan (Deason 1939).

Bangham and Hunter (1939) examined 7 mottled sculpins from western Lake Erie, and reported only 2 infected, each with a single larval cestode (*Proteocephalus ambloplitis* and *Proteocephalus* sp.).

Bangham (1955) examined 8 specimens from Lake Huron and Manitoulin Island. Seven were infected with parasites identified as larval trematodes *Tetracotyle* sp., and *Diplostomum* sp.

Rabb and McDermott (1962), in a survey of southern Ontario streams for *Aeromonas salmonicida*, the bacterium causing furunculosis in fishes, found that *C. bairdi* was a carrier along with the brook trout, *Salvelinus fontinalis*, but the importance of this discovery is not known.

Hoffman (1967) gave a long list of parasites infecting this species in North American waters as follows: protozoans (1), trematodes (12), cestodes (5), nematodes (2), acanthocephalans (4), molluscs (1), and crustaceans (1).

Relation to man Hallam (1959) suggested that *C. bairdi* was a useful indicator of waters suitable for brook trout, but confirming evidence is lacking and this role seems more usually associated with *C. cognatus*. However, in southern Ontario waters this role may well be valid and deserves further study. *C. bairdi* may also serve as a supplementary forage fish for game species besides brook trout, but confirming evidence is also lacking.

From time to time, both *C. bairdi* and *C. cognatus* have been regarded as more or less serious predators on trout eggs but such views are not supported by facts. Both species may compete with trout for food but such competition is unlikely to be serious except under marginal conditions for trout.

Lake dwelling populations of mottled sculpins can be most easily sampled by night seining.

Nomenclature

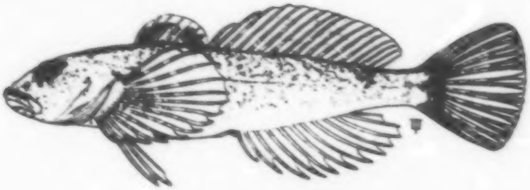
Cottus Bairdii — Girard 1850: 410 (type locality Mahoning River, Ohio)
Cottus Richardsoni Agass. — Agassiz 1850: 300
Uranidea Richardsoni Jordan and Gilbert — Cox 1896a: 48
Cottus ictalops (Rafinesque) — Bean 1903b: 635
Cottus bairdii Girard — Hubbs 1926: 75
— Hubbs and Lagler 1958: 118
Cottus meridionalis — Hubbs 1926: 75
Cottus hubbsi — Bailey and Dimick 1949: 2
— McAllister and Lindsey 1961: 83
Cottus bairdi Girard — Bailey 1951: 196
Cottus girardi Robins — Savage 1962: 848
Cottus bendirei — Bailey and Bond 1963: 1

Etymology *Cottus* — an old European name; *bairdi* — named for Spencer Fullerton Baird, first United States Fish Commissioner.

Common names Mottled sculpin, Miller's thumb, Columbia sculpin, blob, gudgeon, freshwater sculpin. French common name: *chabot tacheté*.

SLIMY SCULPIN

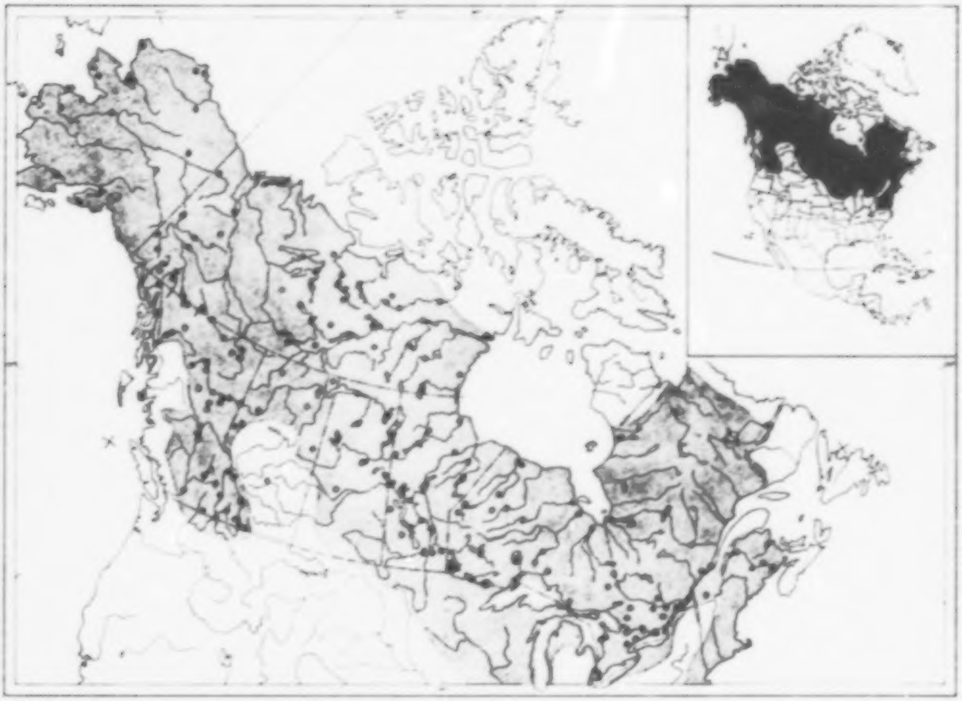
Cottus cognatus Richardson



Description Body of characteristic cottoid shape with flattened and laterally expanded head, average total length about 3 inches (76 mm), body depth about equal to body width anteriorly, but posterior portion strongly compressed laterally; the caudal peduncle of moderate depth. Head flattened dorsoventrally and expanded posteriorly, the eyes on top of head, head length 22.0–27.9% of total length, maxillary extends posteriorly to below eye, 1 large preopercular spine directed upward and posteriorly, 2 small spines directed downward, all covered by skin; gill membranes broadly joined to isthmus, operculo-mandibular pores 10–10 or 11–11 (2 on tip of chin); eye relatively large, its diameter 20–30% of head length; snout moderate, rounded in dorsal view; mouth moderate, upper lip protruding beyond lower; fine teeth developed on upper and lower jaws and on vomer, but no teeth on palatines. Branchiostegal rays 6,6(57), 6,5(1). Fins: dorsals 2, the first small, spiny of 7(5), 8(58), or 9(5) spines, base short, the second dorsal with long base, soft rayed, 14 (McPhail and Lindsey 1970), 15 (McPhail and Lindsey 1970), 16(24), 17(40), 18(5), or 19 (McAllister 1964a) rays; caudal slightly rounded; anal with long base, soft rayed, 10(3), 11(23), 12(39), 13(4), or 14 (McAllister 1964a) rays; pelvics small of 1 spine and 3,3(41) soft rays, only 1 (Manitoba) occurrence of 1 spine and 4,4 rays but fourth ray usually reduced when present, as in British Columbia and northwestern populations (*see* McPhail and Lindsey 1970 and *also* Walters 1955, who noted 4 pelvic fin rays in 13 Alaskan specimens); pectorals large, fanlike, rays 12(1), 13(10), 14(24), 15(11), or 16(1). Typical scales absent but small prickles may be present behind pectoral fins; lateral line incomplete, terminating below centre of second dorsal fin. Vertebrae 31(9), 32(8), 33(3), 34 (McPhail and Lindsey 1970) or 35 (McPhail and Lindsey 1970), caudal vertebrae 20–24 (McAllister 1964a).

Colour Overall colouration usually dark brown with darker mottling, lighter on the sides and white or nearly so on ventral surface but considerable variation is exhibited depending upon background and other factors (*see* Miller and Kennedy 1946). Often with two, dark, oblique saddle marks, one under each of anterior and posterior portions of second dorsal fin, and a less well-defined bar at base of caudal fin. First dorsal fin darkly pigmented basally, almost clear marginally, second dorsal, caudal, and anal may be lightly barred, pectoral fins usually with wide bands. Chin uniformly pigmented, not noticeably mottled. Breeding males dark overall, with a broad reddish orange edge on spinous dorsal fin.

Systematic notes Throughout its extensive North American range, *C. cognatus* exhibits even more morphological variation than *C. bairdi*. *See* McAllister (1964a) for a detailed discussion of the variability of these two species, *C. cognatus* and *C. bairdi*, in eastern Canada, and *see also* under *Systematic notes* for *C. bairdi*. (For regional morphometric and meristic data *see also* Dymond 1926; Walters 1955; Lindsey 1956; McAllister and Bleakney 1960; McAllister and Lindsey 1961; McAllister 1964a, 1968; and McPhail and Lindsey 1970). This plasticity has resulted in part, in the allocation of at least two subspecies to Canadian waters: *Cottus cognatus cognatus*, said to occur in western North America from the Columbia River through British Columbia to the Territories and Alaska; and *C. c. gracilis*, the form occurring in eastern North America from the Great Lakes and from Virginia, north to Ungava. The implications of the morphological variability as related to subspecific designation have been discussed by McAllister and Lindsey (1961) and more recently by McPhail and Lindsey (1970). These authors used, among other characters, the occurrence of a double fin ray on the last anal fin basal element, and the four rays in the pelvic fin (although this fourth ray is often reduced). These features were considered characteristic of the northern type, while the single anal ray on the last basal element and three rays in the pelvic fin were characteristic of the southern type, of the Great Lakes and eastward. Note that the pelvic fin ray count is a frequently used key character for distinguishing *C. cognatus* (3 pelvic rays) and *C. bairdi* (4 pelvic rays), a useful character in eastern Canada, but much less reliable in the west. However, as McPhail and Lindsey noted, wide areas in northern Canada are occupied by populations that have the split anal fin ray but are intermediate



in pelvic ray counts, while in the Columbia, Fraser, and Peace rivers of British Columbia are populations intermediate in both characters. These British Columbia populations also present problems in the development of theoretical paths of postglacial redispersal, which further discourages the acceptance of subspecific designations.

Under the circumstances, the allocation of subspecific names to Canadian populations seems undesirable.

Distribution The range of this species extends through northern North America to extreme northeastern Siberia where it occurs on the Chukot Peninsula and east to the Anadyr River (as *Cottus kaganowskii* Berg, but *see* Walters 1955; McAllister and Lindsey 1961; and McPhail and Lindsey 1970; for reviews of the status of this species). In its extensive North American range, it occupies more northerly waters than its close relative *C. bairdi*. It occurs from Virginia, Labrador, and Ungava on the east, westward through most of northern North America to Alaska, and on St. Lawrence Island in the Bering Sea.

In Canada, the slimy sculpin occurs in scattered localities in New Brunswick, in Labrador from Northwest River and Flour Lake of the Hamilton River system, thence through most of Quebec north to Ungava. From these eastern and northern limits the species occurs widely, in suitable habitats, throughout Ontario, Manitoba, most of Saskatchewan, and the Territories (but not in the main Mackenzie River). It is apparently absent from the Cypress Hills region of Saskatchewan, much of southern Alberta, and most of the lower portions of coastal British Columbia drainages.

There appear to be no positive records for Nova Scotia.

Biology The spawning habits of this sculpin are not well known in Canada and, although some studies have been conducted, few have been published. The earliest account is that of Richardson (1836) who first described the species. He noted that he took the species in considerable numbers in the clear waters of Great Bear Lake in May, when it resorted to stony shallows to spawn. He also noted that some individuals were full of eggs and were only 2½ inches long. However, we have much more information on the morphological and meristic variation of the species than of its ecology, not illogically, because *C. bairdi* and *C. cognatus* are difficult to distinguish and there would be little point in attempting to study ecology until identities were established. An M.A. thesis concerning the biology of this species in the waters of northern Saskatchewan was prepared by the late W. Van Vliet (1964), but has not been published. It contains a wealth of information which should be made available in published form.

The following outline of the spawning procedure is taken largely from Koster (1936), who discussed the spawning of both *C. cognatus* and *C. bairdi* in northern New York waters. The procedure is basically the same for both species and essentially similar to the spawning behaviour of other members of the genus. Koster (1936) gave average temperatures of 41° F (5° C) for the onset of spawning in Cayuga Lake, and 50° F (10° C) for a spring stream, tributary to Fall Creek, N.Y. The ripe male selected a spawning site under a rock or ledge (or sometimes under a submerged tree root), the female was courted and entered the nest and, presumably after additional courting, deposited adhesive eggs in a mass on the ceiling of the nest, then left or was driven out. The nest usually contained eggs from more than one female. The male guarded the nest and young, at times continuing in this duty, according to Koster (1936) even after the young had begun to feed. (*See also* spawning of *C. bairdi*.)

Details concerning egg sizes, rate of development, appearance of the larvae and growth rates are largely unavailable in published form but were determined by Van Vliet (1964) for northern Saskatchewan populations. Diameters of water hardened eggs were 2.3–2.6 mm. Age 3 females, at lengths of about 4 inches (100 mm), produced approximately 1400 eggs. In Montreal River, spawning occurred during early May at about 46° F (8° C) and the eggs hatched in about 4 weeks.

McPhail and Lindsey (1970) reported size to 4.7 inches (120 mm) but specimens available to us measured only to 4.3 inches (109 mm).

The habitat occupied seems to vary greatly depending, probably, upon available substrate and temperature. In general, it occupies deeper waters of lakes and cooler streams and occurs further north than *C. bairdi*. It frequents rocky or gravelly streams and lake bottoms, darting swiftly from place to place when disturbed. In Ungava, Dunbar and Hildebrand (1952) reported it abundant in tide pools in company with threespine sticklebacks. Although common in rocky shallows of lakes in the north (as indicated by Richardson's 1836 account) slimy sculpins are frequently found in cool spring-fed streams in the south and east. Descriptions of habitat and capture were provided by Dymond (1926), Harkness and Hart (1927), Fowler (1948), and Harper (1948, 1961). In Lake Michigan Deason (1939) concluded that it was more abundant in the northern part of the lake where it occurred from near shore to about 300 feet (91.4 m) but was found at least as deep as 420 feet (128 m). It should be noted that Deason's specimens were obtained from stomachs of lake trout and burbot and the depths are those at which these predators were caught.

The exploratory surveys conducted in the Great Lakes by the United States Fish and Wildlife Service in the late 1950's and early 1960's yielded much useful information on depth distribution and abundance. The data for Lake Michigan tend generally to indicate shallower depths than those given by Deason. There appeared to be little seasonal variation in depth. Slimy sculpins were taken in numbers from 18–270 feet (5.5–82.3 m), most commonly in depths of 120–240 feet (36.6–73.2 m), while the deepwater sculpin *(Myoxocephalus quadricornis)* occurred more commonly below these depths. Dryer (1966) analysed the exploratory data for Lake Superior and noted that the largest catches of slimy sculpins were made at 300–354 feet (91.4–107.9 m).

Detailed food studies for Canadian populations have not been published but available evidence suggests that the primary food is invertebrate bottom fauna, particularly aquatic insect larvae; the species eaten depends upon availability which, in turn, is related to habitat, but a wide range of insect groups are involved. Studies to the mid-1930's were summarized by Koster (1937), who quoted Richardson's (1836) findings in the stomach of one of the type specimens from Great Bear Lake, which contained "fragments of *dytisci* and other fresh-water insects and *crustaceae*, and also of some small fish." Studies conducted in upper New York State showed that aquatic insects, crustaceans, small fishes, and some plant materials were consumed, but, aquatic insect larvae and nymphs made up more than 50% of the diet and often 85% or more. The more important insect groups were mayflies, caddisflies, dipterous larvae, stoneflies, and dragonflies. Large fish tended to eat the larvae of larger species.

A number of larger, predaceous fishes, such as lake trout, speckled trout, northern pike, and burbot feed upon this sculpin to a greater or lesser degree, depending upon its availability. Its role in the diet of lake trout and burbot in the Great Lakes was discussed by Dymond (1928b), Van Oosten and Deason (1938), Deason (1939), and Dryer et al. (1965), but the importance of this role vanished with the disappearance of the lake trout from most of the Great Lakes. It is eaten by lake trout, northern pike, and other species in inland lakes in various parts of the country, such as British Columbia (Clemens et al. 1945), and Saskatchewan (Rawson 1959, 1960, 1961).

Cooper (1918) reported the cestode *Schistocephalus solidus*, from a Lake Ontario specimen of this sculpin (using the name *Uranidea formosa*). Lawler (1952) reported finding the cestode *Triaenophorus nodulosus* encysted in the liver of a specimen from Heming Lake, Man., the first record of this parasite in the slimy sculpin in North America.

Van Vliet (1964) discussed the parasites and diseases of the slimy sculpin in Saskatchewan waters. His studies included Myxosporidian cysts (the author suggested that these were caused by *Myxobolus* sp.) *Ligula* sp., and *T. nodulosus*.

Bangham and Adams (1954), in their survey of the parasites of freshwater fishes from British Columbia, reported the following parasites from *C. cognatus* (which they called "mottled sculpin"), trematodes Gyrodactyloidea; nematodes *Rhabdochona cotti* and *Haplonema* sp.; and encysted fluke metacercaria.

Relation to man Inexperienced brook trout fishermen are sometimes startled to see a small, grotesque creature, with a large head and large pectoral fins and bulging eyes, dangling from the end of their line — more than likely their first and perhaps only contact with this sculpin, for they are occasionally caught on small hooks.

The use of the slimy sculpin as a bait fish for trout dates back at least 50 years, for Dymond (1926) remarked that it was a favourite bait, under the name "cockatouch," for brook trout in Nipigon waters. Many of the trout that won the "Nipigon Trophy" were caught on "cockatouch." It is also used occasionally as live bait for trout in other parts of eastern Canada.

The slimy sculpin is a common associate of both lake trout and brook trout and forms part of the food supply of both. It may also compete with the brook trout for food, since both eat aquatic invertebrates, but the extent of such competition is unknown. (*See* Koster (1937) for a discussion of the question.)

Predation by slimy sculpins on eggs deposited by lake trout and brook trout was discussed also by Koster (1937) but there was virtually no evidence that sculpins fed upon eggs of either species and only rare instances of predation on young brook trout.

Nomenclature

Cottus cognatus (Richardson) — Richardson 1836: 40 (type locality Great Bear Lake, N.W.T.)
Cottus gracilis — Heckel 1840: 148
Uranidea quiescens — DeKay 1842: 61
Cottus Franklini Agass. — Agassiz 1850: 303
Cottus formosus — Girard 1852: 58
Cottus philonips E. and E. — Eigenmann and Eigenmann 1892: 963
Uranidea boleoides (Girard) — Cox 1896a: 48
Uranidea formosa Girard — Cox 1896a: 49
Uranidea gracilis (Heckel) Putnam — Cox 1896a: 51
Uranidea franklini (Agassiz) — Jordan and Evermann 1896–1900: 1967
Uranidea hoyi Putnam — Jordan and Evermann 1896–1900: 1969
Cottus chamberlaini Evermann and Goldsborough — Evermann and Goldsborough 1907b: 308

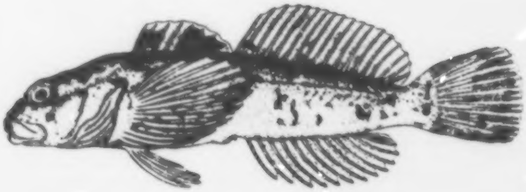
(*see* McAllister and Lindsey 1961, for additional synonyms)

Etymology *Cottus* — an old European name: *cognatus* — related (to the European species, *C. gobio*).

Common names Slimy sculpin, Miller's thumb, cockatouch, slimy muddler, common slimy muddler, northern sculpin, stargazer, Bear Lake bullhead. French common name: *chabot visqueux*.

SHORTHEAD SCULPIN

Cottus confusus Bailey and Bond



Description (This description is based upon the original description by Bailey and Bond (1963) and that of McAllister and Lindsey (1961) for *Cottus* sp.) Body typically cottoid, heaviest forward, decreasing in size posteriorly to a medium caudal peduncle, posterior portion of body noticeably compressed laterally. Head short, 26.3–33.8% of standard length, rather round when viewed from above, maxillary extends posteriorly to below pupil of eye, 2 or 3 preopercular spines, preoperculo-mandibular pores variable, 8–1–8 to 10–10 (only 3% with median chin pore); eye moderate; mouth large, round in dorsal aspect; teeth well developed on upper and lower jaws, moderately developed and widely spaced on palatines and separated from vomerine tooth patch. Fins: dorsals 2, the first with short base, spiny, 7–10 spines, the second dorsal longer and higher than first, soft rayed, of 15–19 (usually 16–18) rays; caudal slightly rounded; anal with moderately long base, soft rayed of 12–14 rays; pelvics small, usually 1 spine and 4 (or 5) soft rays; pectorals large and fanlike, 13–15 rays. Typical scales absent and prickles, if present, restricted to an area behind pectoral fin insertion; lateral line never complete, terminates below ray 10–16 of second dorsal fin. Vertebrae 33–35, caudal vertebrae 22, 23, or 24.

Colour McAllister and Lindsey (1961) described the colour of a form listed as *Cottus* sp., but which referred to this species, and the following colour description is from their account. Body light brown-yellow with dark mottlings. Sides usually pale, without bars, sometimes three dark, mottled bars under second dorsal fin. Post-interorbital region dark. Chin lightly and evenly speckled. First dorsal fin dark anteriorly, and posteriorly between the rays, sometimes with a median band.

Systematic notes This species is very difficult to distinguish from *Cottus bairdi*.

Distribution This sculpin occurs in the Pacific drainage area of North America, in the Puget Sound and Columbia River basins only.

In Canada, the shorthead sculpin has an exceedingly restricted range, and is to be found only in the Flathead River in southeastern British Columbia.

Biology The shorthead sculpin has only recently been recognized as a distinct species and, hence, little is known of its life history or habits. The only information readily available is that published by Bailey and Bond (1963) in their original description, and McAllister and Lindsey (1961).

It inhabits the riffles of small cold streams, usually farther upstream than other cottids, but may also inhabit large rivers, such as the Columbia. It occurs sympatrically with *C. cognatus* in the Flathead River, B.C. It may grow to a length of 4.1 inches (105 mm).

Relation to man It is of minor importance in the Canadian fauna because of its very restricted distribution.

Nomenclature

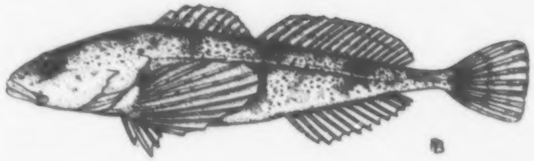
Cottus confusus	— Bailey and Bond 1963: 12 (type locality Salmon R., tributary to Snake R., Idaho)
Cottus sp.	— McAllister and Lindsey 1961: 84

Etymology *Cottus* — an old European name; *confusus* — clouded, referring to the irregular and indistinct body pigmentation.

Common names Shorthead sculpin. French common name: *chabot à tête courte*.

TORRENT SCULPIN

Cottus rhotheus (Smith)



Description Body typically cottoid, heaviest forward, decreasing in size posteriorly to a narrow caudal peduncle, body noticeably compressed laterally on posterior portion only, average size about 4 inches (102 mm). Head large 26.8–30.1% of total length, maxillary extends posteriorly to below eye, 3 preopercular spines, operculomandibular pores 11–11, 2 pores on tip of chin; eye moderate, its diameter 20.2–26.8% of head length; mouth large (larger than *asper* at all sizes; *see* Northcote 1954, for comparative measurements); teeth strong and well developed on upper and lower jaws, palatines, and vomer, palatine tooth patches long and in contact with vomer tooth patch. Fins: dorsals 2, the first with short base, spiny, of 7, 8 (usually), or 9 spines, the second dorsal longer and higher than first, soft rayed, of 15 (usually), 16, or 17 rays; caudal rounded; anal with long base, soft rayed, 11, 12 (usually), or 13 soft rays; pelvics small, reduced, of 1 spine and 4 rays; pectorals large and fanlike, rays 15–18. Typical scales absent, but well-developed prickles usually on back, sides, and sometimes on caudal peduncle, but prickles may be restricted to patch behind pectoral fin; lateral line usually complete, sometimes extending onto caudal fin. Vertebrae, caudal 20–23.

Colour Overall colouration brown or greyish brown with darker mottling. There are two distinct and dark saddle-like blotches that angle down and forward on the back under the second dorsal fin; lighter on lower sides and white below. Chin distinctly mottled. Dorsal, caudal, and, sometimes, anal and pectoral fins with bands or bars of pigment. Outer edge of the first dorsal fin thickened and orange coloured on spawning males.

Systematic notes Extensive geographic variability of *C. rhotheus* throughout its range was discussed by Bailey and Dimick (1949) and McAllister and Lindsey (1961). The latter authors provided tables of comparative meristics to show the range of values for fin rays, chin pores, and vertebrae. *C. rhotheus* is considered to be most closely related to *C. carolinae* of the southeastern United States but is also similar to *C. ricei* in having prickles, a wrinkled chin, slender caudal peduncle, and semitubular nostrils. *See* McAllister and Lindsey for additional information.

Distribution The torrent sculpin occurs in the west coast of North America in the Columbia River and Puget Sound drainages, and in North Thompson River (Fraser system).

In Canada, it occurs only in British Columbia where it is known from the following regions: in the Similkameen system; in the Kettle River; in the main Columbia River from Kinbasket Lake through the Big Bend, the Arrow lakes and south to the U.S. border; in Kootenay Lake and upper Kootenay system in the Cranbrook area. Recently found in the North Thompson system near Little Fort and at Heffley (Carl et al. 1967).

Biology Spawning is thought to occur about June. Northcote (1954) observed that fish caught in June were inactive and in spawning condition but no spent fish were found. He considered that the species did not spawn until at least late spring of its second year. McAllister and Lindsey (1961) stated that it attains a total length of 6.1 inches (155 mm).

The torrent sculpin is primarily a stream species but may also occur over beaches in large lakes. Northcote observed that it inhabited the upper littoral zone of the Arrow Lakes and was taken by beach seine (with *Cottus asper*) on several occasions.

Young and partly grown (to 55 mm) torrent sculpins ate planktonic crustaceans in very early stages but mainly aquatic insect larvae, particularly of midges and mayflies. Above this size range, fish became increasingly important in the diet until it was almost the exclusive food of sculpins 70 mm or larger. Minnows, particularly redside shiners and squawfish, were most frequently eaten. Northcote demonstrated that it has a proportionally larger mouth than *C. asper* and at comparable lengths can eat larger food items. Predation on coho salmon fry by torrent sculpins was studied by Patten (1962) but the sculpin was considered to feed only incidentally on salmon fry.

Bangham and Adams (1954) examined 38 specimens from Dry Lake in the Columbia drainage. All specimens were infected with larvae of the trematode *Diplostomulum* sp.; some with the larvae of trematodes *Tetracotyle* sp., and adult Gyrodactyloidea; acanthocephalans, *Neoechinorhynchus rutili* and *Pomphorhynchus bulbocolli*; and in the digestive tract, the immature form of the cestode *Proteocephalus* sp.

Hoffman (1967) listed the protozoan *Cryptobia lynchi*, cestode *Proteocephalus* sp., and the acanthocephalan *N. rutili*.

Relation to man This species is of no known direct importance. Possibly its feeding habits and early ability to consume other fishes may bring it into conflict with man's interests but this cannot be said to be the case at present.

Nomenclature

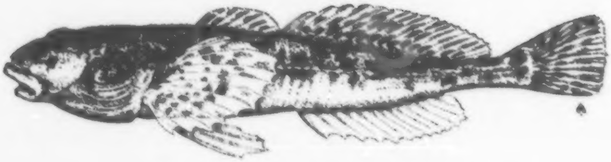
Uranidea rhothea	— Smith 1882: 347 (type locality Spokane Falls, Wash.)
Cottus rhotheus Rosa Smith	— Jordan and Evermann 1896–1900: 1946
Cottus rhothea (Rosa Smith)	— Jordan, Evermann, and Clark 1930: 383
Cottus rhotheus (Rosa Smith)	— Carl and Clemens 1948: 107
Cottus rhotheus (Smith)	— Bailey et al. 1970: 58

Etymology *Cottus* — an old European name; *rhotheus* — rushing of the torrent, referring to habitat.

Common names Torrent sculpin. French common name: *chabot de torrent.*

SPOONHEAD SCULPIN

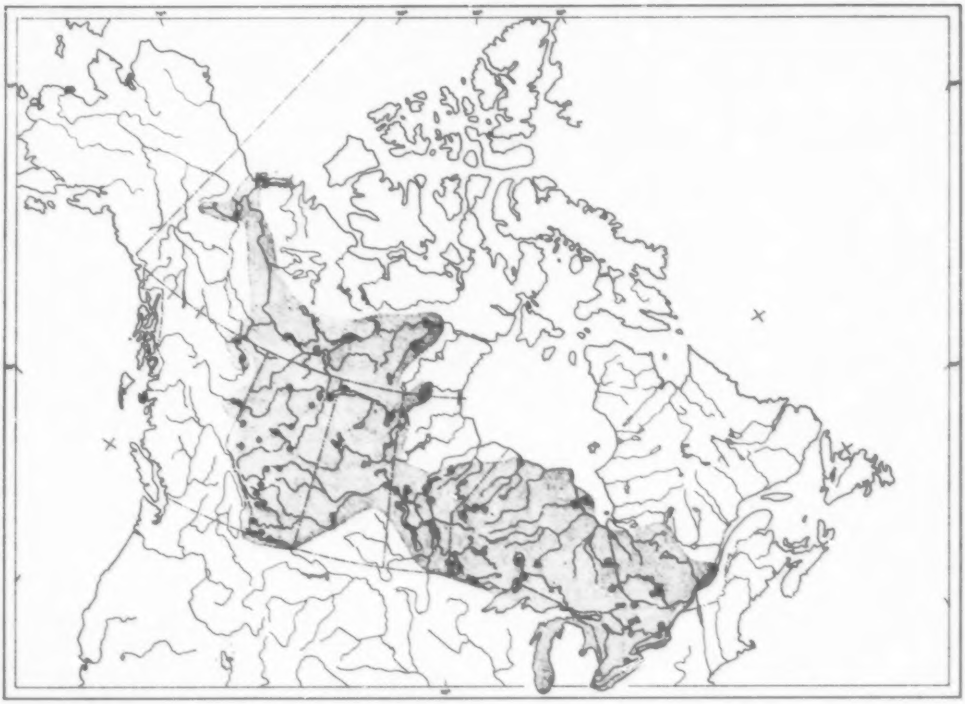
Cottus ricei (Nelson)



Description Body of peculiar shape, with flattened head, almost tubular body (especially of adults), laterally compressed posteriorly and with a narrow caudal peduncle, average total length about 2.0–2.5 inches (51–64 mm). Head decidedly flattened dorsoventrally, and spatulate in dorsal view, the eyes noticeably on top of head, head length 23.4–30.0% of total length, maxillaries extending posteriorly to a point in front of eye, dorsally a distinctive W-shape to posterior margin of premaxillary groove, 2, 3, or 4 preopercular spines, but uppermost well developed and hooked or curved upward and backward; gill membranes broadly joined to isthmus, operculo-mandibular pores 10–1–10, a single pore at tip of chin; eye diameter 19–30% of head length; snout blunt, mouth relatively small, teeth developed on upper and lower jaws and on vomer but no palatine teeth. Fins: dorsals 2, the first rather small, spiny, 7(2), 8(43), 9(3), 10 (McAllister and Lindsey 1961) spines, base short, the second dorsal with a long base, soft rayed, 15(3), 16(16), 17(13), or 18(16) rays; caudal slightly rounded; anal with long base, soft rayed, of 11 (McAllister 1957 personal communication), 12(15), 13(24), 14(8), or 16(1) rays; pelvics small, ventral in position, of 1 spine and 4 rays; pectorals very large and fanlike, rays 14–16. Typical scales absent, body more or less covered with small prickles, sometimes restricted to head region only on large females; lateral line complete. Vertebrae 34 or 35, caudal vertebrae 23–25.

Colour Overall colouration light brown or tan in lower Great Lakes, but distinctly darker northward. Darker saddle-like blotches on back. Often four in number, the first three occurring through the base of the second dorsal fin, the fourth on the peduncle, but these dorsal markings not necessarily present especially on large Great Lakes specimens. Remainder of back variously speckled with light or dark brown spots that also occur on pectoral, both dorsal and caudal fins and also faintly, at times, on the anal fin. Pelvic fins and ventral surface generally immaculate but populations on inland lakes may exhibit scattered pigmentation on ventral surface including chin and especially caudal peduncle. Small specimens may have a distinct vertical bar at caudal base. Fish (1932) provided a detailed description of the first Lake Erie specimen, which was 27.5 mm long.

Systematic notes The spoonhead sculpin is rather stable in its meristic and morphometric characters and is the most distinctive member of the genus *Cottus* in North America, with *C. rhotheus* as perhaps its closest relative on this continent. Its possible relationship to another prickly sculpin, *C. sibiricus* of northern Asia, was noted by Wynne-Edwards (1952) and McAllister and Lindsey (1961), who also suggested *C. spinulosus* and *C. gobio* as possible Eurasian relatives; *see also* Walters (1955). For additional systematic information *see* Dymond (1926), McAllister (1962b), and McAllister and Lindsey (1961).



Distribution North American distribution is almost entirely restricted to Canadian waters except in the Great Lakes basin where it occurs throughout the Great Lakes, including Lake Michigan, and in inland United States waters in Lake Charlevoix, Mich., and in lakes on Isle Royale.

In Canada, the spoonhead sculpin ranges widely. The known eastern limit is the St. Lawrence River, Que., near Neuville, Saint Nicolas, and St. Petronille, Ile d'Orléans (Vladykov 1949b). West from this, it is found in lakes in Gatineau County and in southwestern Quebec (Delisle and Van Vliet 1968). Throughout Ontario, it occurs in suitable habitats, from lakes Ontario, Erie, Huron, Superior, and Nipigon, north to Lake Abitibi, Fort Severn (on Hudson Bay) and the James Bay shore waters of Akimiski Island. In Manitoba, it has been reported from a few localities in the Lake Winnipeg region, in the Saskatchewan River, and the mouth of the Nelson River at York Factory (Keleher and Kooyman 1957), and in Nueltin Lake on the northern boundary. In Saskatchewan, it has been recorded from the Saskatchewan River, and from lakes Wollaston and Athabasca. Recorded from many parts of Alberta, from the Milk (a questionable record) and Bow rivers and Waterton Lakes region in the south, to the North and South Saskatchewan rivers, Lesser Slave Lake and the Athabasca River in the north. It occurs in the Peace River below the canyon, and in the Mackenzie River system of northeastern British Columbia; in the Northwest Territories in Great Slave Lake and the lower Mackenzie River (McAllister 1962b) and the Thelon River system (Beverly and Dubawnt lakes) of the Hudson Bay drainage.

Wynne-Edwards (1952) erroneously recorded *C. ricei* in Alaska, but there are no valid records (Walters 1955).

Many, perhaps most, of the locality records for *Cottus ricei* are based upon one or two specimens, these often from lake trout or burbot stomachs, or those washed up on shore. Indeed, the original description was of a specimen found on the shore of Lake Michigan. Hence, the species may be more widely distributed than our present records indicate.

Biology Little is known of the biology of this sculpin. Even our knowledge of its distribution is most inadequate and only rarely are enough specimens found in any one locality to warrant life history studies.

The time of spawning is not known but recent evidence suggests that spawning occurs in late summer or early fall. Delisle and Van Vliet (1968) reported that milt was exuded, under slight pressure, from males caught August 1, 1967, at a depth of 140 feet (42.7 m) in Pemichangan Lake, Gatineau County, Que. The temperature at 140 feet was 40.1° F (4.5° C). Ovaries examined by us from Ontario specimens contained larger eggs in August than in June or July and exceedingly small eggs in December.

The size attained is relatively small. Most specimens range from about 1.6–2.4 inches (40–60 mm) but many of these are possibly immature. Specimens in excess of 3 inches (76 mm) are not uncommon, particularly when trawls are used for sampling. Dymond (1926) reported 3.25 inches (82 mm) as the maximum size seen at Lake Nipigon. A number of specimens in excess of 4 inches (102 mm) have been taken in Lake Erie by otter trawls; one of these, a female, measured 4.7 inches (120 mm) in total length. The maximum size known is 5.3 inches (134 mm) total length, caught in gillnets in Pemichangan Lake, Que. (Delisle and Van Vliet 1968).

Habitat and depth distribution are almost as poorly known as other aspects of its biology. Inland and northward it has been caught in small swift streams, turbid rivers, or the inshore shallows of and deeper waters of lakes (Dymond and Scott 1941; Ryder et al. 1964; Delisle and Van Vliet 1968; and McPhail and Lindsey 1970). In lakes, its relative depth distribution is probably intermediate between *C. cognatus* and *Myoxocephalus quadricornis*, at least in the Great Lakes area. Dymond (1926) and Greene (1935) noted that it was usually found at shallower depths than the deepwater sculpin, *M. quadricornis*. Exploratory fishing in the Great Lakes by vessels of the United States Bureau of Commercial Fisheries yielded much new information on depth distribution of many species, cottids included. Brief accounts of the results were reported in cruise reports of the MV *Siscowet* and MV *Cisco*. Captures of *C. ricei* in Lake Superior to depths of at least 62 fathoms (372 feet; 114.4 m) were reported. Occasional specimens were caught in other trawl tows at depths of 12–25 fathoms (72–150 feet; 21.9–45.7 m), but up to 25 specimens were taken at 36 fathoms (216 feet; 65.8 m). These were July and August samples and suggest that the optimum depth might be in the vicinity of 200 feet, if the field records are not distorted by spawning movements. Deason (1939) gave a depth range in Lake Michigan of "... from shore to about 75 fathoms" (i.e., to 450 feet).

Some of the literature on depth range is confused and misleading. Trautman (1957) gave the depth for the first Lake Erie record as "22 metres (132 feet)." The 22 metres is correct. McPhail and Lindsey (1970) gave a depth range in the Great Lakes to "200 m (600 ft)." The 200 metre depth is possibly in reference to *Myoxocephalus quadricornis*, which inhabits depths to 100 fathoms (Deason 1939; Eddy and Surber 1960; and others). We were unable to validate a depth of 600 feet for *C. ricei* and suggest that Deason's 75 fathoms (450 feet) is possibly more realistic.

There is no detailed information on food, and we can only assume that planktonic crustaceans (in deep lakes) and aquatic insect larvae (in inshore regions) figure prominently in the diet.

The spoonhead sculpin has been demonstrated to be a regular item in the diet of Great Lakes fishes. Deason reported 347 specimens from the stomachs of Lake Michigan lake trout and burbot, and as many as 33 from a single stomach. However, the number of specimens in a single stomach was usually less than 10. Deason also reported that 3 specimens were removed from the stomach of a whitefish caught in Charlevoix Lake, Mich. Rawson (1959) reported one from the stomach of a lake trout caught in Wollaston Lake, Sask.

Predation on *C. ricei* by lake trout and burbot in Lake Michigan and Lake Superior is perhaps only of historical interest since these predators have entirely disappeared or been greatly reduced in numbers. How *ricei* has responded to this reduction in predator pressure is unknown.

The parasitic fauna of the species is unknown.

Relation to man The spoonhead sculpin is of interest zoogeographically, since its presence in a body of water provides information on the geological or glacial history of the region. Economically, it is of interest because it was a natural food of lake trout and burbot in the Great Lakes and is still a natural food of these species in inland lakes.

Nomenclature

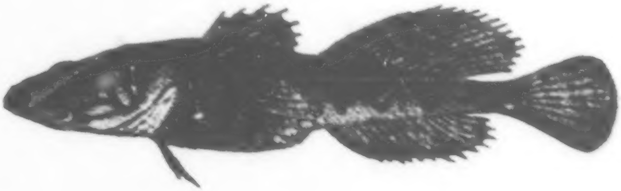
Cottopsis ricei	— Nelson 1876: 40 (type locality Lake Michigan off Evanston, Ill.)
Uranidea pollicaris	— Jordan and Gilbert 1883b: 222
Cottus onychus	— Eigenmann and Eigenmann 1892: 963
Cottus ricei Nelson	— Jordan and Evermann 1896–1900: 1952
Cottus pollicaris (Jordan and Gilbert)	— Jordan and Evermann 1896–1900: 1953

Etymology *Cottus* — an old European name; *ricei* — after its discoverer, M. L. Rice.

Common names Spoonhead sculpin, Rice's sculpin, spoonhead muddler. French common name: *chabot à tête plate*.

DEEPWATER SCULPIN

Myoxocephalus quadricornis (Linnaeus)

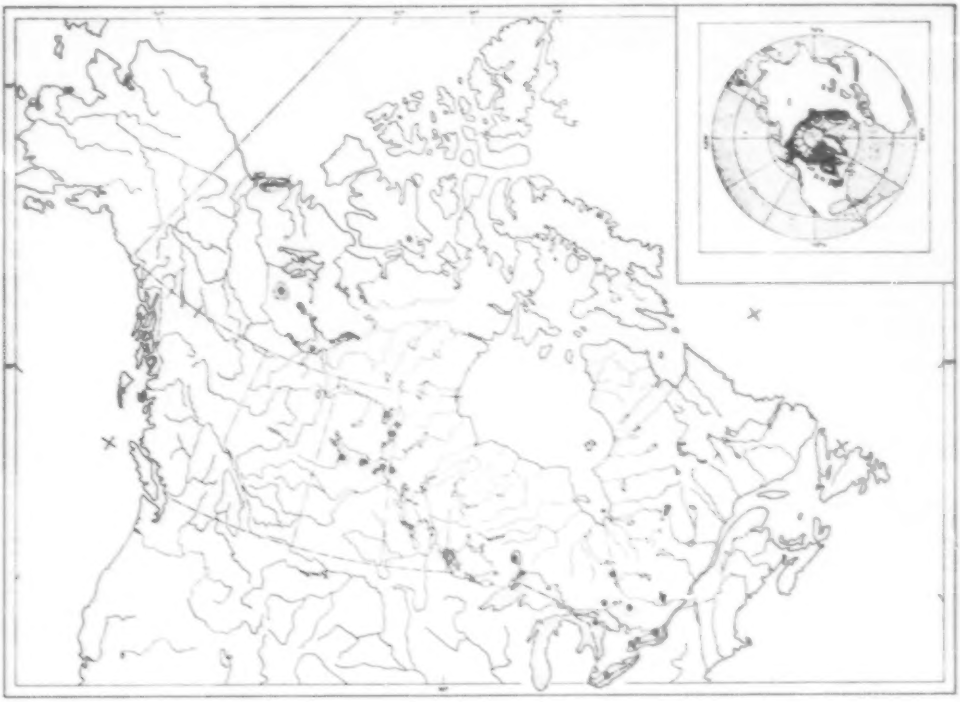


Description Body elongate, average total length 2–3 inches (51–76 mm), heaviest forward, body depth and width about equal below first dorsal, decreasing steadily posteriorly to a slender caudal peduncle. Head distinctly flattened dorsoventrally and expanded, its greatest width at the origin of the uppermost preopercular spines, head length 25.9–30.2% of total length, maxillary extending posteriorly to below middle of eye or beyond, gill membranes meeting at an acute angle and free from isthmus, preoperculomandibular pores absent, 4 preopercular spines in all, the upper 2 large and slender, appearing as 1 enlarged bifurcate spine, pointing upward and posteriorly, the remaining 2 smaller, directed downward (preopercular spines most useful in identification especially for partially digested specimens), the frontal and parietal spines, so obvious in most adult marine *M. quadricornis*, are absent. Eyes on top of head, close together, eye diameter relatively small, 18.1–23.8% of head length; snout broadly rounded in dorsal view; mouth large, more or less terminal; teeth fine, in brushlike bands on upper and lower jaws, larger on palatines, vomer, and even tongue. Branchiostegal rays 6,6(16), 7,7(1). Fins: dorsals 2, the first small, spiny, of 7(19), 8(27), 9(13), or 10(2) spines (data combined with McAllister 1961), base short, second dorsal with long base, soft rayed, 11(3), 12(13), 13(25), 14(19), 15(9), 16(1) rays (data combined with McAllister 1961), second dorsal often greatly enlarged on males (Jacoby 1961), dorsal fins distinctly separated by distance about equal eye diameter; caudal more or less square or truncate; anal with long base, soft rayed, 11(1), 12(13), 13(23), 14(21), 15(11), or 16(1) (data combined with McAllister 1961); pelvics small, of 1 spine and 3(17) soft rays, rarely 4(1), spine concealed in fleshy sheath with first ray; pectorals large, fanlike, 15 (McPhail and Lindsey 1970), 16(9), 17(8), or 18 (McPhail and Lindsey 1970). Typical scales absent, spines or prickles present only above lateral line, usually fewer than 30; lateral line complete or nearly so, many specimens in eastern Canadian inland populations have incomplete lateral lines. Vertebrae 37(3), 38(3), or 39(4) (marine populations in Hudson Bay ranged 39–42).

Colour Overall colouration grey-brown (when freshly caught); back and upper part of sides grey-brown, becoming lighter about midline of sides, and light below. Back and sides with light speckling or mottling, back with four to seven thin, dark, saddle-like marks. Pelvic fins lightly pigmented or immaculate, remaining fins variously barred. *See* colour illustration facing p. 90.

Systematic notes The taxonomy and postglacial distribution of the deepwater sculpin in North America has received considerable attention in recent years. The interested student should see papers by Walters (1955), Ricker (1959), McAllister (1961), Johnson (1964), and, especially, McPhail and Lindsey (1970). Hubbs and Lagler (1964) and others have proposed a subspecific designation, *Myoxocephalus quadricornis thompsonii*, for the North American freshwater form. McPhail and Lindsey also accepted this subspecies concept and, in addition, proposed adoption of the familiar common name, "deepwater sculpin." This common name is appropriate because this freshwater form does regularly live at greater depths than the marine form, which McPhail and Lindsey suggested might be designated *Myoxocephalus quadricornis quadricornis*, the fourhorn sculpin. The common name, deepwater sculpin, is at variance with the name fourhorn sculpin, proposed in the checklist of common and scientific names of the American Fisheries Society (Bailey et al. 1970), but we recommend its use because it is descriptive, it does distinguish the North American freshwater populations from the marine ones, and it has been in general use in North American literature for decades.

The deepwater sculpin is usually referred to as a glacial relict in both Europe and North America because, theoretically, it, together with the relict crustaceans *Mysis relicta* and *Pontoporeia affinis*, all originally occupying arctic, marine, or brackish waters, was pushed southward, along with the salt water, in front of the advancing ice sheets. Eventually the ice retreated, forming proglacial lakes as it did so, and leaving behind the deepwater sculpin and its ever-present invertebrate associates that form its food supply. Other theories proposed to explain this sculpin's freshwater distribution, which even now must be considered incompletely known, involve the voluntary migrations of marine sculpins into fresh water, and finally, dispersal by invasions of



sea water up the St. Lawrence and inland from Hudson Bay. These theories were thoroughly discussed by McAllister (1961). The proglacial lake theory proposed by Ricker (1959) has gained general acceptance to explain adequately most of the inland occurrences. Modification of this theory, however, may be required to account for some inland occurrences. Martin and Chapman (1965) suggested that sculpins moved downstream in the Fossmill outlet channel of the Algonquin stage of the Great Lakes, as the glaciers retreated. Delisle and Van Vliet (1968) considered that to be the most logical explanation for the occurrences in Heney Lake in the Gatineau region of southwestern Quebec. Voluntary movements into fresh water by marine forms may have taken place and may be on-going, especially in the arctic. But all populations have not necessarily been derived in the same way. The extremely large size formerly attained in Lake Ontario (to at least 9.2 inches (234 mm)) compared with the 4–5 inch (102–127 mm) length in the other Great Lakes and the even smaller size attained northwestward, suggests the possibility of a different origin. This view is strengthened by the size of individuals being found in the Gatineau region of Quebec. Unfortunately, the origin of the Lake Ontario population will probably remain forever a mystery for the species has been extirpated, possibly a result of DDT pollution.

Distribution *Myoxocephalus quadricornis* is circumpolar in distribution. It occurs in two forms, one marine and the other fresh water. The marine populations live in cold, salt, and brackish water in the northern hemisphere. Freshwater populations are found in Europe, Asia, and North America, where in the Great Lakes region they extend south to about the 42nd parallel of latitude, the southern limit of world distribution. North American freshwater populations, generally regarded as glacial relicts, are confined entirely to Canadian waters except for Torch Lake, Mich., and the Great Lakes.

The freshwater form is distributed from western Quebec and the lower Great Lakes region of Ontario through the upper Great Lakes and, thence, in a wide arc through Manitoba, Saskatchewan, and the Northwest Territories to Great Bear Lake and Victoria Island. The range in Quebec and Ontario has been considerably extended by the work of M. J. Dadswell, who, following Van Vliet, has most successfully employed a small bottom trawl in a number of inland lakes. In many inland lakes, deepwater sculpins were known previously only from stomach contents of burbot and lake trout. The species is now known to occur in Quebec in Heney Lake, Gatineau District; in Ontario in Raven Lake, south of Abitibi; Cedar Lake, Algonquin Park; Fairbank Lake near Sudbury; in all the Great Lakes and Lake Nipigon; in Manitoba in West Hawk Lake in the southeast, and Athapapuskow, south of Flin Flon; in Saskatchewan in Reindeer, Mirond, MacKay, la Ronge, la Plonge and Wollaston lakes; in the Northwest Territories in Great Slave, La Martre, Keller, and Great Bear lakes. A freshwater form, possibly separately derived from the marine form, is known in at least three lakes in the eastern half of Victoria Island.

In Lake Ontario, the deepwater sculpin was once so abundant that it was considered to be a nuisance when caught in the gillnets set for lake trout. It now appears to have been extirpated, for not a single specimen has been seen in 10 years and even extensive experimental trawling has failed to capture it.

Biology We know next to nothing about the breeding biology of the deepwater sculpin because of the considerable depths it inhabits, but available evidence indicates that spawning occurs in summer, or early fall. Some evidence suggests year-round spawning, at least in the Great Lakes.

Spawning probably took place in late August or early September in Lake Ontario, for Dymond et al. (1929) recorded large masses of nearly ripe eggs in specimens caught August 12, 1927. Females containing large eggs have also been caught in July in Great Bear Lake and in Keller Lake, N.W.T. The care afforded eggs and young by related cottids suggests that parental care is practised by the deepwater sculpin also. McPhail and Lindsey remarked on the presence of a large clump of eggs in the mouth of one of the Lake Ontario specimens caught July 18, 1927, and queried if this was accidental or if it implied parental care. The second dorsal fin of males is much enlarged but its function, although probably related to breeding, is unknown. This fin and the pectoral bear small, hard, rough tubercles in the mature male. In Lake Erie, Fish (1932) described and illustrated specimens 12.5 and 16.2 mm long, caught from the latter part of July to mid-August, 1928, indicating earlier spawning in Lake Erie than in Lake Ontario.

Hopefully, more will be learned by studying populations in smaller, inland lakes, such as Heney Lake in the Gatineau region of Quebec. The need for great care in working in deep water with Scuba gear is emphasized by the unfortunate death of William Van Vliet in Heney Lake in 1968, while engaged in a study of this species.

Growth data is also lacking but reference has already been made to the comparatively large size formerly attained in Lake Ontario. One specimen on hand in the ROM collection measures 9.2 inches (235 mm) in total length. Deason (1939) reported two Lake Michigan specimens 4.0 and 4.3 inches (102 and 109 mm) standard length, considered to be exceptionally large. The largest specimen reported from Great Slave Lake was 2.7 inches (69 mm) standard length.

Considerable evidence on depth distribution in the Great Lakes has been gathered. On October 3, 1927, Dymond et al. (1929), using $1\frac{1}{2}$-inch gillnets, caught specimens at depths of 300–411 feet (91.4–125.3 m) and as many as 655 individuals at 370 feet (112.8 m). Exploratory surveys in Lake Michigan in 1961 by United States Fish and Wildlife Service reported deepwater sculpins ranged from 150 to 600 feet (44.7–182.9 m) but were most abundant at 240–300 feet (73.2–91.4 m). Yields as high as 130–200 pounds for 30-minute hauls of a commercial balloon trawl at these depths were recorded.

The greatest depths of capture reported for deepwater sculpins is probably 1200 feet (365.9 m), by trawl in Lake Superior (Dryer 1966). McPhail and Lindsey reported specimens removed from two lake trout netted at 1200 feet (365.9 m) in Great Bear Lake.

Information on the food of deepwater sculpins is scattered. In Lake Nipigon, *Pontoporeia affinis* and chironomid larvae were found in the stomachs of this species (Dymond 1926). Stomachs of Great Bear Lake specimens were reported to contain *Mysis*, the copepod, *Limnocalanus*, and chironomid larvae (McPhail and Lindsey 1970), and Lake Ontario specimens, caught in 1926 and 1927, on re-examination, were found to contain *P. affinis*, *Mysis relicta*, and chironomid larvae (McAllister 1961). Since *Mysis* and *Pontoporeia* are always associated with this sculpin, they might be expected to form a fairly regular part of its diet.

The deepwater sculpin is a regular prey of only the lake trout and the burbot. In Lake Ontario, Dymond (1928b) recorded as many as 27 deepwater sculpins from a single lake trout stomach, the average number per stomach being 5.4; as many as 32 were recorded from a single burbot stomach while the average for 64 stomachs was 11.2. In Lake Michigan, the deepwater sculpin was formerly a most significant item in the diet of lake trout and burbot. Deason (1939) reported a total of 1215 specimens removed from 65 collections of stomachs of these two species, and as many as 139 specimens from a single stomach collection. In a review of the lake trout of Lac la Ronge, Sask., Rawson (1961) remarked that the deepwater sculpin was one of the first fish of suitable size and in suitable location to provide food for young trout.

The acanthocephalan *Echinorhynchus salmonis* occurred in the intestine of one specimen caught in a gillnet in Lake Huron in 96 feet (29.3 m) of water, southwest of South Bay (Bangham 1955).

Relation to man The deepwater sculpin is obviously of considerable interest to those biologists concerned with Canadian problems involving postglacial dispersal and zoogeography.

There is little doubt that this small fish was an important food for lake trout before the virtual disappearance of this latter commercial species from much of the Great Lakes. Rawson (1961) considered it to be important in the diet of lake trout in certain lakes in Saskatchewan.

Nomenclature

Cottus quadricornis	— Linnaeus 1758: 264 (type locality Baltic Sea)
Triglopsis thompsonii	— Girard 1852: 65, 66, 67, 71
	— Evermann and Kendall 1901: 488
Triglopsis Stimpsonii	— Hoy 1873: 319
Triglopsis thompsoni	— Nash 1908: 103
	— Halkett 1913: 32
	— Hubbs 1926: 74
	— Radforth 1944: 86
	— Scott 1954: 113
Triglopsis ontariensis	— Jordan and Thompson 1910a: 75
Myoxocephalus quadricornis	— Jacoby 1953: 1
Myoxocephalus thompsoni	— Walters 1955: 318
Myoxocephalus quadricornis thompsonii (Girard)	— Hubbs and Lagler 1958: 118
Myoxocephalus thompsonii	— McAllister 1961: 44
	— Delisle and Van Vliet 1968: 2733

(*see* McAllister 1961 for more detailed synonymy)

Etymology *Myoxocephalus* — head like a dormouse; *quadricornis* — four horned.

Common names Deepwater sculpin, fourhorn sculpin, scorpion fish, sculpin, lake sculpin, deep-water blob, Great Lakes fourhorn sculpin. French common name: *chabot de profondeur*.

Suggested Reading — Cottidae

BAILEY, J. E. 1952. Life history and ecology of the sculpin *Cottus bairdi punctulatus* in southwestern Montana. Copeia 1952: 243–255.

BAILEY, R. M., and C. E. BOND. 1963. Four new species of freshwater sculpins, genus *Cottus*, from western North America. Occas. Pap. Mus. Zool. Univ. Mich. 634: 27 p.

BAILEY, R. M., and M. F. DIMICK. 1949. *Cottus hubbsi*, a new cottid fish from the Columbia River system in Washington and Idaho. Occas. Pap. Mus. Zool. Univ. Mich. 513: 18 p.

DEASON, H. J. 1939. The distribution of cottid fishes in Lake Michigan. Pap. Mich. Acad. Sci. Arts Lett. 24: 105–115.

DELISLE, C., and W. VAN VLIET. 1968. First records of the sculpins *Myoxocephalus thompsonii* and *Cottus ricei* from the Ottawa Valley, southwestern Quebec. J. Fish. Res. Bd. Canada 25: 2733–2737.

JOHNSON, L. 1964. Marine–glacial relicts of the Canadian arctic islands. Syst. Zool. 13: 76–91.

KOSTER, W. J. MS 1936. The life-history and ecology of the sculpins (Cottidae) of central New York. Ph.D. Thesis. Cornell Univ., Ithaca, N.Y. (unnumbered).

1937. The food of sculpins (Cottidae) in central New York. Trans. Amer. Fish. Soc. 66: 374–382.

KREJSA, R. J. 1967a. The systematics of the prickly sculpin, *Cottus asper* Richardson, a polytypic species. Part I. Synonymy, nomenclatural history, and distribution. Pac. Sci. 21: 241–251.

1967b. The systematics of the prickly sculpin, *Cottus asper* Richardson, a polytypic species. Part II. Studies on the life history, with especial reference to migration. Pac. Sci. 21: 414–422.

LÖNNBERG, E. 1933. Some remarks on the relict forms of *Cottus quadricornis* L. in Swedish freshwater lakes. Ark. Zool. 24A(7): 23 p.

LUDWIG, G. M., and C. R. MORDEN. 1969. Age, growth and reproduction of the northern mottled sculpin (*Cottus bairdi bairdi*) in Mt. Vernon Creek, Wisconsin. Milwaukee Pub. Mus. Occas. Pap. Natur. Hist. 2: 67 p.

MARTIN, N. V., and L. J. CHAPMAN. 1965. Distribution of certain crustaceans and fishes in the region of Algonquin Park, Ontario. J. Fish. Res. Bd. Canada 22: 969–976.

MCALLISTER, D. E. 1961. The origin and status of the deepwater sculpin, *Myoxocephalus thompsonii*, a nearctic glacial relict. Bull. Nat. Mus. Can. Contrib. Zool. 172: 44–65.

1964. Distinguishing characters for the sculpins *Cottus bairdii* and *C. cognatus* in eastern Canada. J. Fish. Res. Bd. Canada 21: 1339–1342.

1968. Mandibular pore pattern in the sculpin family Cottidae. Bull. Nat. Mus. Can. Contrib. Zool. 223: 58–69.

McAllister, D. E., and C. C. Lindsey. 1961. Systematics of the freshwater sculpins *(Cottus)* of British Columbia. Bull. Nat. Mus. Can. Contrib. Zool. 172: 66–89.

Northcote, T. G. 1954. Observations on the comparative ecology of two species of fish, *Cottus asper* and *Cottus rhotheus,* in British Columbia. Copeia 1954: 25–28.

Ricker, W. E. 1960. A population of dwarf coastrange sculpins *(Cottus aleuticus).* J. Fish. Res. Bd. Canada 17: 929–932.

Robins, C. R., and R. R. Miller. 1957. Classification, variation, and distribution of the sculpins, genus *Cottus*, inhabiting Pacific Slope waters in California and southern Oregon, with a key to the species. Calif. Fish Game 43: 213–233.

Savage, T. 1962. *Cottus girardi* Robins, a synonym of *Cottus bairdi* Girard. Copeia 1962: 848–850.

1963. Reproductive behavior of the mottled sculpin, *Cottus bairdi* Girard. Copeia 1963: 317–325.

Shapovalov, L., and A. C. Taft. 1954. The life histories of the steelhead rainbow trout *(Salmo gairdneri gairdneri)* and silver salmon *(Oncorhynchus kisutch)* with special reference to Waddell Creek, California, and recommendations regarding their management. Calif. Dep. Fish Game Bull. 98: 375 p.

Sinclair, D. C. 1968. Diel limnetic occurrence of young *Cottus asper* in two British Columbia lakes. J. Fish. Res. Bd. Canada 25: 1997–2000.

GLOSSARY

GLOSSARY

Abdomen — the lower surface of the body, especially the part between the pectoral fins and the anus.

Abdominal pelvic fins — said of pelvic fins when located on abdomen, far removed from head.

Accessory caudal rays — short rays on the upper and lower anterior portions of the caudal fin.

Accessory pectoral scale — an enlarged or elongated scale at dorsal base of pectoral fin in some herringlike fishes.

Adipose eyelid — transparent tissue around margin of eye.

Adipose fin — a fleshy fin on the back behind the dorsal fin, as in trouts, salmons, whitefishes, smelts, and catfishes.

Alevin — newly hatched, incompletely developed fishes (usually salmonids) still in nest or inactive on bottom, living off stored yolk.

Allopatric — living in geographically separated places *(cf. sympatric).*

Ammocoete — a name applied to the larval form of lampreys.

Amphicoelous — concave both before and behind, the usual condition of fish vertebrae.

Amphipods — crustaceans belonging to the group that includes freshwater shrimps.

Anadromous — ascending rivers from the sea to spawn, as do shad and some salmonid fishes.

Anal — referring to the anus or vent.

Anal fin — the fin on the median ventral line behind the anus.

Anal papilla —an appendage or protuberance in front of the genital pore and behind the vent in sculpins (*cf. genital papilla*).

Annulus (plural *annuli*) — a mark or marks formed on a fish scale or bone each year.

Anterior — the front portion; in front.

Antrorse — turned forward (of maxillary).

Anus — the posterior external opening of the alimentary canal: the vent.

Articulated — attached by means of a movable joint: jointed.

Asymmetrical — not symmetrical: one side not the mirror image of the other, as in the head of a flatfish or flounder.

Axillary process — a daggerlike projection at the base of the pectoral or pelvic fins.

Barb — hooklike serration, as on pectoral and dorsal fin spine of carp and catfishes.

Barbel — an elongated, hairlike projection, usually about the mouth, chin, or nose, as in the cods and sturgeons.

Basal — (of fins) skeletal support of fin ray(s).

Basibranchials (or *hyoid*) — the three median bones on the floor of the gill chamber, joined by the ventral ends of the five gill arches.

Basihyal — the median bone which joins the basibranchials posteriorly and which forms the "tongue" anteriorly, in the floor of the mouth.

Benthic — living on or near to the bottom (*cf. pelagic*).

Bifid — see bifurcate.

Bifurcate — divided into two branches.

Branchial — of the gills.

Branchiostegal rays — bony rays supporting the membranes which close the branchial or gill cavity under the head.

Breast — see pectoral.
Buccal — of the mouth.

Caecum (plural *caeca*) — a blind sac connected with the alimentary canal.
Canines — conical teeth which are larger than the rest.
Cardiform — brushlike, said of fine teeth of uniform length in brushlike bands or patches.
Cardiod scales — notched, specialized scales, *see* p. 347.
Carinate — keeled: having a sharp median ridge as on the belly of certain herring-like fishes.
Catadromous — going down rivers to the sea to spawn as does the American eel.
Caudal — pertaining to the tail or caudal fin.
Caudal peduncle — the fleshy end of the body behind the anal fin and before the caudal or tail fin: the tail minus the tail fin: the "wrist."
Centrum — the body of a vertebra.
Ceratohyal — anterior bone to which the bases of the branchiostegal rays are attached.
Chin — anterior ventral portion of the lower jaw.
Chironomids — true flies belonging to the midge family.
Chondrocranium — the cartilagineous brain case in fishes around which covering bones are laid down in higher (bony) fishes.
Cladocera — a group of small crustaceans called water fleas, which includes *Daphnia.*
Cline (adjective *clinal*) — progressive change or gradient in structure or feature of animals that follows a geographic gradient such as latitude or altitude (e.g. increase in number of fin rays in a species northwards).
Cloaca — a chamber in the lower part of the gut into which empty the ducts from the kidney and reproductive organs. It has one external opening, cloacal aperture, instead of separate anal (vent) and urinogenital openings.
Compressed — laterally: flattened from side to side.
Copepoda (or *copepods*) — a group of small crustaceans which includes *Cyclops* and *Argulus.*
Crenate — with a scalloped or notched margin (as on opercular flap at edge of gill cover of sunfishes).
Crustaceans — members of the large class, Crustacea, of the phylum Arthropoda (all of which have a hard jointed external skeleton), including shrimps, crayfish, and water fleas.
Ctenoid — said of scales of most spiny-rayed fishes having posterior margin of scale with needle-like projections.
Cusp — a point or projection on a tooth.
Cycloid — said of the scales (having smooth margins) of typical soft-rayed fishes.

Deciduous — said of scales that are easily rubbed off and thus not firmly attached.
Decurved — bent downwards.
Dentary — a bony element of the lower jaw usually bearing teeth.
Dentate — with toothlike notches.
Denticulated — having fine toothlike projections.
Dentition — said of teeth, their arrangement and structure.
Depressed — flattened from above downwards, i.e. dorsoventrally, as in head of cottids.

Depth — the vertical diameter or distance through, as of the body of fishes.
Dimorphism — existing in two forms.
Distal — farthest from the centre; peripheral.
Dorsal — pertaining to the back.
Dorsal fin — a fin on the back, usually central in position supported by rays or spines.

Emarginate — said of caudal fin having a slight notch or indentation.
Epihyal — posterior bone to which the bases of the branchiostegal rays are attached.
Estuarine — said of fishes that occupy estuaries.
Euryhaline — able to tolerate a wide range of osmotic pressures in the environment; a fish that can move freely from a saltwater to a freshwater environment.
Eye diameter — the horizontal diameter of the eye ball — in contrast to iris diameter, which is the distance across the black aperture in the centre of the eye, or orbit diameter, which is the horizontal distance between anterior and posterior margins of the socket.

Falcate — scythe-shaped.
Falciform — *see falcate.*
Fauna — the assemblage of animals inhabiting a region.
Filament — slender or threadlike, said of certain elongated fin rays in some fishes.
Filamentous — *see filament.*
Fimbriate — having a frilled edge.
Fingerling — young fish, usually late in first year.
Fork length — distance from the anteriormost margin of head to tip of middle ray of the caudal fin.
Frenum — fold of skin that limits the movements of an organ, e.g. membrane across snou of some darters.
Frontal spines — those on the head between the posterior margins of the eyes.
Fry — young fish, newly hatched, after yolk has been used up and active feeding commenced.
Fulcrum (plural *fulcra*) — spinelike structures bordering the anterior rays of the fins in some fishes.
Fusiform — spindle-shaped; referring to the form of fishes that have the body tapering both anteriorly and posteriorly, and slightly or not at all compressed.

Gape — (of the mouth), the distance from the front to the angle of the mouth, crude index of size of mouth, habit of spawning fishes of opening mouth very widely.
Gastropoda — a class of the phylum Mollusca, including snails, that usually have coiled shells.
Genital papilla — a projection near the anus that carries the external opening to the reproductive system (*cf. anal papilla*).
Genotypic — refers to hereditary characteristics (*cf. phenotypic*).
Gill arches — the bony supports of the gills.
Gill cover — the bony covering of the gill cavity, composed of opercular bones (*see operculum*).
Gill membrane — the thin wall of skin supported by the branchiostegals, and closing the gill cavity below.
Gill rakers — a series of bony projections along the anterior edge of the gill arch. Gill-raker counts are usually made on the left anterior arch. Every raker is counted, including the

bony rudiments at the ends of the series that may be difficult to see except under magnification.

Graduated — regular or steady increase in length, as of the spines in the fins of some fishes.

Gular plate — bony plate or plates located behind the chin and between the sides of the lower jaw.

Haemal spine — the lower or ventral spine of a caudal vertebra.

Head length — distance from the most anterior point of the head to the posterior edge of the opercle.

Hemibranch — a rudimentary gill on the inner face of the operculum.

Hermaphrodite — having both male and female reproductive organs in one body.

Heterocercal — unequally lobed; said of the tail or caudal fin of a fish where the upper lobe is larger than the lower, and in which the last few vertebrae of the vertebral column are bent upward.

Homocercal — equally lobed; said of the tail or caudal fin when upper and lower lobes are more or less equal, and the backbone or vertebral column ends at the middle of the base of the fin.

Hyoid — see basibranchial.

Hypurals — the expanded haemal spines of the posterior vertebrae, which support the rays of the caudal fin.

Ichthyology — the scientific study of fishes.

Imbricated — overlapping, like shingles on a roof.

Immaculate — without spots or pigment pattern, usually white or colourless.

Inferior — used in reference to mouth when snout projects beyond lower jaw.

Infraoral — below the mouth; used in reference to the teeth immediately below the oesophageal opening in lampreys.

Insertion — (of a fin) the posterior end of the base, the part of the base farthest from the head.

Interneurals — the bones to which the dorsal fin rays are attached.

Interopercle — a bone of the lower part of side of the head; a part of the operculum.

Interorbital space — narrowest distance across the head, between the bony edges of the orbits or eye sockets.

Isocercal — with the vertebrae becoming progressively smaller backward, as in the codfishes.

Isospondylous — with the anterior vertebrae simple; said of the herringlike fishes which lack the Weberian apparatus.

Isthmus — the fleshy space beneath the head and between the gill openings.

Jugular — pertaining to the throat; said of the pelvic fins when located in advance of the point of attachment of the pectorals.

Keel — a sharp compressed edge on the ventral surface between the paired fins, or the lateral surface of the caudal peduncle.

Keeled — see carinate.

Kelt — a dark, thin, recently spawned-out (or spent) Atlantic salmon or trout.

Larva (plural *larvae*) — the young of an animal when differing markedly from the adult.
Lateral line — series of porelike openings (to sensory canal) along the sides of a fish.
Laterally compressed — flattened from side to side.
Lateral teeth or *tooth plates* — in lampreys, those tooth plates lying on either side of the opening to the pharynx.
Leptocephalus — a name applied to the larval form of the eels.
Lingual — pertaining to the tongue.
Lingual teeth — teeth on tongue: the serrated teeth on the tongue of lampreys.
Littoral — inhabiting the bottom of a lake near shore.
Lunate — crescentlike, in reference to shape of caudal or tail fin.

Major rays (or *principal rays*) — longer (at least ¾ height of fin) obvious fin rays as opposed to anterior rudiments often not visible (*see* p. 24); often comprise all branched rays plus one anterior unbranched ray.
Mandible — the lower jaw.
Mandibular (or *submandibular*) *pore* — small sensory opening in the undersurface of the bones of the lower jaw.
Maxillary — the posterior and lateral element of the upper jaw.
Median — lying in the midline that divides an animal into right and left halves.
Melanophore — black pigment cell.
Metamorphosis — period of transformation from larval to adult form.
Molar — with a flattened, grinding surface; said of teeth.
Mouth — (inferior) — mouth below snout, snout obviously overhanging mouth;
(oblique) — line of the mouth (when closed) at an angle of 45° or greater;
(subterminal) — mouth slightly overhung by snout, not quite terminal;
(terminal) — tips of upper and lower jaw forming foremost part of the head;
(ventral) — mouth on ventral surface of head, as in sturgeons.
Myomere — *see myotome.*
Myotome — a muscle plate, a section of the repeated muscle units corresponding to the flakes of a cooked fish.

Nape — part of body immediately behind head on dorsal surface.
Nasal — one of the paired bones on front of a fish's head, usually beside the nostril.
Neural spine — the upper or dorsal spine of a vertebra.
Notochord — the embryonic cartilagineous vertebral column persistent in lampreys, sharks, and rays.
Nuptial tubercles — small, often pimple-like projections that occur on head or body or lower fins of males of some species (e.g. rainbow smelt) during breeding period.

Obsolete — only faintly apparent, or absent.
Occiput — the extreme back of the head on dorsal surface.
Ocellus — an eyelike spot.
Oesophagus — the beginning of the digestive tract immediately after the mouth.
Opercle — the large rectangular bone of the gill cover.
Opercular flap — a backward prolongation of the posterior angle of the opercle.
Opercular gill — a rudimentary gill on the inner face of the operculum as in gars and sturgeons (= *hemibranch*).

Operculum (also called *gill cover*) — the bony covering of the gill cavity composed of opercular bones, i.e. preopercle, interopercle, subopercle, opercle.

Opisthocoelous — convex in front, concave behind, the condition in the vertebrae of gars alone.

Orbit — the bony eye socket.

Origin — (of a fin) the anterior end of the base; the end of base nearest the head.

Ostracoda — a group of invertebrate animals enclosed in bivalve shells; includes *Cypris*.

Oviparous — said of fishes that lay eggs that develop usually in the external environment.

Ovoviviparous — said of those animals that retain the eggs within the body of the female in a brood chamber where development of the embryo takes place, the eggs perhaps deriving some nourishment from the female, but without the strong umbilical attachment to a placenta as in mammals; the true condition of so-called "live-bearing" fishes.

Paired fins — pectoral and pelvic fins, in contrast to vertical fins.

Palatines — paired bones on roof of mouth.

Papilla (plural *papillae*) — a small fleshy projection or ridge.

Papillose (or *papilate*) — covered with papillae.

Parietal — one of the roofing bones of the skull.

Parr — life stage of salmonid fishes, usually in first or second year, body marked with parr marks.

Parr marks — dark vertical marks on the sides of young salmonid fishes.

Pectinate — having teeth like a comb.

Pectoral — the anterior ventral portion of a fish; the breast.

Pectoral arch — shoulder girdle; the complex of bones usually connected with the skull, to which the pectoral fins are attached.

Pectoral fins — the most anterior or uppermost of the paired fins, usually dorsal to pelvic fins.

Pectoral girdle — see pectoral arch.

Peduncle — the fleshy end of the body behind anal fin (*see caudal peduncle*).

Pelagic — living in open waters, in contrast to bottom-living or inshore species.

Pelvic arch (or *girdle*) — the bones to which the pelvic fins are attached; pubic bones.

Pelvic axillary process (*scale*) — a slender scale-like process or tab of tissue that develops at the base of the pelvic fins of many salmonid and other bony fishes.

Pelvic fin — ventral, paired fin lying below the pectoral fin or between it and the anal fin.

Percomorph — used in reference to those fishes in the order Percomorphi.

Peritoneum — the membranous inner lining of the abdominal cavity.

Pharyngeal teeth — bony toothlike projections from the fifth or pharyngeal gill arch. In Cyprinidae they consist of a vertical arc of bone with the teeth projecting at right angles toward the midline. Teeth are easily broken off while the arch is being removed; tooth counts should be made under magnification, and empty sockets or broken tooth bases included in the counts.

Pharynx (adjective *Pharyngeal*) — the first portion of the digestive tract behind the mouth.

Phenotypic — characteristics that result from modification of the individual by the environment (*cf. genotypic*).

Physoclistous — having the swim bladder isolated from the oesophagus.

Physostomous — having the swim bladder connected to the oesophagus by an open duct.

Piscivorous — fish-eating.

Plankton — small aquatic plants and animals, sometimes microscopic.
Plate — hard, bony shield in various places on body, usually larger than scales, found especially in sturgeons and sticklebacks.
Plicate — with wrinkle-like folds.
Posterior — behind.
Prefrontal — a roofing bone of the skull.
Premaxillary — the paired bones usually bearing teeth that form the front of the upper jaw in troutlike fishes, and the entire lower border of the upper jaw in higher percomorph fishes.
Preopercle — the most anterior of the opercular series, the bone of the cheek.
Preorbital — a large bone lying in front of the eye.
Prickles — small, fine, sometimes curved spines, on, or in place of, scales.
Principal rays — longer (at least ¾ height of fin) obvious fin rays as opposed to anterior rudiments often not visible (*see* p. 24); often comprise all branched rays plus one anterior unbranched ray.
Procurrent — name applied to the stiff rays at base of caudal fin.
Protractile — a term used in reference to the premaxillaries when they can be extended forward; such premaxillaries are separated from the sloping front of the head (forehead) by a groove.
Proximal — nearest the point of attachment.
Pyloric — used in reference to pylorus; that section of the intestinal tract immediately following the stomach.
Pyloric caeca — fingerlike extensions attached to the pylorus.

Ray — an articulated or jointed rod that supports the membrane of a fin.
Redd — the gravel nest of salmonid fishes.
Retrorse — turned backward (of maxillary).
Rhombic (or *rhomboid*) *scale* — the type of heavy, bony, diamond-shaped, nonoverlapping scales found in gars.
Rudimentary — undeveloped or poorly developed.

Scale radius — line radiating from the focus of a scale. The angle subtended by the outer two is used to distinguish between species.
Scute — a bony or horny plate.
Serrate — saw-toothed; like a saw.
Shoulder girdle — the complex of bones usually connected with the skull, to which the pectoral fins are attached (*see pectoral girdle*).
Smolt — life stage in salmonid fishes, individual usually 1–3 years of age, turning silvery, preparing to migrate out of stream or lake to sea, or out of stream to large lake.
Snout — technically that part of the head of a fish in front of the eyes.
Snout length — distance from the most anterior point of the head or upper jaw, to the front margin of the eye socket.
Soft dorsal — the dorsal fin or portion of it that consists of soft rays only (*cf. spinous dorsal*).
Spine — fin rays that are not branched, are without obvious segments, and are more or less stiffened and sharpened at the apex; or similar straight or curved, sharp structures on other parts of the body (operculum, cheek).

Spinous dorsal — the dorsal fin or portion of it which consists of spines only.

Standard length — distance from the most anterior part of the head to the posterior margin of the last whole vertebral centrum.

Stay (or *membranous connection*) — a fleshy bridge from side of body to upper base of pelvic fin.

Stenohaline — unable to tolerate a wide range of osmotic pressures in the environment; i.e. cannot move freely from salt to fresh water.

Striations — grooves or streaks.

Subequal — nearly but not quite equal.

Subopercle — the bone below the opercle (*see operculum*).

Suborbitals — a series of small bones below the eye.

Subspecies — a group of local populations of a species, inhabiting a geographic subdivision of the range of the species, and differing taxonomically from other populations of the species.

Supplemental maxillary — a small bone lying on the upper posterior edge of the maxillary.

Supraoccipital — the unpaired bone at the back of the skull usually with a crest above.

Supraoccipital crest — the posterior median ridge on the back of the skull.

Supraoral — above the mouth.

Swim bladder (also called *gas bladder, air bladder*) — gas-filled sac in dorsal portion of body cavity of most fishes which aids in buoyancy, and in respiration in some.

Sympatric — living in overlapping ranges and not denied the opportunity to interbreed by any geographic barrier (*cf. allopatric*).

Symphysis — the point of junction of two bones as in the two parts of the lower jaw in front; the tip of the chin.

Synonym — an additional scientific name for the same animal. When the same species is described by two different writers and given different names, one of these will be retained and used, the other one is called a synonym. A list of disused names is called the synonymy of a species.

Teleost — a name applied to fishes having the skeleton fully ossified, in other words a "bony fish" in contrast to a shark which is a cartilagineous fish.

Terete — cylindrical and tapering.

Terminal — at the end (*see mouth*).

Thoracic — pertaining to the chest or thorax; anterior to the abdomen.

Thoracic pelvic fins — pelvic fins which are attached far forward below the pectorals; the pelvic bones usually connected with the shoulder girdle.

Tooth formula — numerical expression of the number of teeth, usually pharyngeal, in each of one or more rows.

Truncate — cut squarely off.

Tubercle — a soft or hardened lump or projection on the surface; usually a modified scale (*see nuptial tubercle*).

Tuberculate — covered with tubercles.

Type — term used in systematics referring to the first-named species in a genus ("type species"), or to the individual specimen on which a taxonomic description is based ("type specimen").

Unicuspid — with a single point or cusp.
Urostyle — the last vertebral segment usually modified (pointed) and reduced.

Velar tentacle — a membranous fingerlike projection that, in lampreys, lies at the junction of the respiratory tube and oesophagus.
Vent — the external opening of the alimentary canal; the anus.
Ventral — on the lower surface; pertaining to the abdomen or belly.
Ventral fins — see pelvic fins.
Vermiculations — markings resembling worm tracks.
Vertebra (plural *vertebrae*) — a single bone of the spinal column.
Vertical fins — the fins (dorsal, anal, and caudal) on the median (centre) line of the body, in contrast to the paired fins (pectorals and pelvics).
Villiform — in the form of villi (fingerlike projections); said of teeth that are slender and crowded closely together in bands.
Vomer — the anterior bone on the roof of the mouth.

Weberian apparatus — the modified first four or five vertebrae in minnows, suckers, carps, catfishes, and their relatives (Ostariophysi), that connect the swim bladder to the inner ear by a series of small bones or ossicles.

INFORMATION ON SPECIMENS USED FOR SPECIES ILLUSTRATIONS

INFORMATION ON SPECIMENS USED FOR SPECIES ILLUSTRATIONS

(Line drawings and photographs)

Pattern and shape of fishes often vary with sex, size, location, and time of year. Usually a single individual, thought by the authors to be characteristic, was used as a basis for both body proportions and pattern in the illustrations. For that reason, information, when available, on sex, total length, locality of capture, date of capture, and catalogue number of the specimen used for the line drawing or photograph is given here. ROM = collection of the Royal Ontario Museum; BC = collection of the Institute of Animal Resource Ecology, University of British Columbia.

41 *Ichthyomyzon castaneus* — Photograph — 380 mm; Manitoba, Red River; Apr. 1957; ROM 19839.

41 *Ichthyomyzon fossor* — Photograph — 150 mm; Ontario, Norfolk Co., Big Creek; June 15, 1955; ROM 17610.

41 *Ichthyomyzon unicuspis* — Photograph — 328 mm; Ontario, Halton Co., Bronte Creek; 1954; ROM 17666.

41 *Lampetra ayresi* — Photograph — British Columbia, Malaspina Strait, Sechelt area; June 21, 1958; BC58-310.

41 *Lampetra lamottei* — Photograph — 187 mm; Ontario, York Co., Highland Creek; Apr. 24, 1957; ROM 19047.

41 *Lampetra richardsoni* — Photograph — 154 mm; British Columbia, Cultus Lake; May 24, 1954; ROM 18557.

42 *Entosphenus tridentatus* — Line drawing borrowed from FRB Bull. 173. Photograph, p. 41 — British Columbia, Port John; 1957; BC57-403.

58 *Lampetra japonica* — Line drawing borrowed from FRB Bull. 173. Photograph, p. 41 — 220 mm; Northwest Territories, Peel River; Oct. 20, 1951; ROM 15143.

69 *Petromyzon marinus* — Line drawing by E. B. S. Logier, no data. Photograph, p. 41 — Ontario, Lake Erie; Dec. 12, 1936; ROM 9603.

80 *Acipenser brevirostrum* — 665 mm; New Brunswick, King's Co., public landing; July 1967; ROM 26419.

82 *Acipenser fulvescens* — 760 mm; Ontario, Leeds Co., St. Lawrence River; May 19–20, 1968; ROM 25887.

90 *Acipenser medirostris* — Borrowed from FRB Bull. 180.

92 *Acipenser oxyrhynchus* — Borrowed from FRB Bull. 155.

96 *Acipenser transmontanus* — Borrowed from FRB Bull. 180.

103 *Lepisosteus oculatus* — Female; 661 mm; Ontario, Kent Co., Lake Erie; Apr. 23, 1955; ROM 17607.

105 *Lepisosteus osseus* — Male; 925 mm; Ontario, Simcoe Co., Georgian Bay; June 3–4, 1967; ROM 25425.

112 *Amia calva* — Female; 470 mm; Ontario, Essex Co., Point Pelee National Park; Aug. 20, 1958; ROM 19960.

120 *Alosa pseudoharengus* — Female; 328 mm; New Brunswick, Charlotte Co., Moores Mill Lake; June 2, 1958; ROM 19680.

128 *Alosa sapidissima* — Male; 528 mm; Ontario, Prescott Co., Ottawa River; Aug. 13, 1936; ROM 10109.

133 *Dorosoma cepedianum* — Male; 325 mm; Ontario, York Co., Lake Ontario; Apr. 20, 1967; ROM 25389.

148 *Oncorhynchus gorbuscha* — Borrowed from FRB Bull. 173.

153 *Oncorhynchus keta* — Borrowed from FRB Bull. 173.

158 *Oncorhynchus kisutch* — Borrowed from FRB Bull. 173.

165 *Oncorhynchus nerka* — Line drawings borrowed from FRB Bull. 173. Upper photo, kokanee — about 508 mm; British Columbia, Kootenay Lake (Courtesy B.C. Game Branch). Lower photo, kokanee — Male; 257 mm; Ontario, Hastings Co., Boulter Lake; ROM 27630. Introduced, stock from Kootenay Lake. (Courtesy Bruce Fallis)

172 *Oncorhynchus tshawytscha* — Borrowed from FRB Bull. 173.

177 *Salmo clarki* — Male; 302 mm; British Columbia, Comox Dist., Anderson Lake; Sept. 1926; ROM 3437.

184 *Salmo gairdneri* — Rainbow trout — Male; 22 pounds; British Columbia, Duncan River. Steelhead trout — Male; 9 pounds; British Columbia, Vancouver Island, Big Qualicum River. Photos by F. T. Pletcher.

192 *Salmo salar* — Borrowed from FRB Bull. 155.

197 *Salmo trutta* — Male; 472 mm; Ontario, Leeds Co., Jones Creek; Apr. 6, 1966; ROM 24051.

201 *Salvelinus alpinus* — Male; 400 mm; Northwest Territories, Tree River Area; Colour pattern taken from film strip.

208 *Salvelinus fontinalis* — Male; 295 mm; Ontario, Ontario Co., Claremont Conservation Area; November 1969.

214 *Salvelinus malma* — Borrowed from FRB Bull. 173.

220 *Salvelinus namaycush* — 625 mm; Ontario.

236 *Coregonus artedii* — Drawing by E. B. S. Logier, no data.

244 *Coregonus autumnalis* — Borrowed from FRB Bull. 173.

255 *Coregonus laurettae* — Borrowed from FRB Bull. 173.

262 *Coregonus sardinella* — Borrowed from FRB Bull. 173.

269 *Coregonus clupeaformis* — Female; 364 mm; Quebec, Koksoak River; July 9–17, 1957; ROM 18921.

278 *Coregonus nasus* — Borrowed from FRB Bull. 173.

281 *Coregonus canadensis* — Male; 328 mm; Nova Scotia, Tusket River Falls; Oct. 27, 1954; ROM 16675.

282 *Prosopium coulteri* — Borrowed from FRB Bull. 173.

286 *Prosopium cylindraceum* — Adult — From FRB Bull. 173; Young — Ontario, Lake Nipigon.

291 *Prosopium williamsoni* — Drawing by E. B. S. Logier, no data.

295 *Stenodus leucichthys* — Borrowed from FRB Bull. 173.

300 *Thymallus arcticus* — Drawing by E. B. S. Logier, no data.

308 *Hypomesus olidus* — Borrowed from FRB Bull. 173.

310 *Osmerus mordax* — Drawing by E. B. S. Logier, no data.

318 *Spirinchus thaleichthys* — Borrowed from FRB Bull. 180.

320 *Thaleichthys pacificus* — Borrowed from FRB Bull. 180.

327 *Hiodon alosoides* — 242 mm; Northwest Territories, Great Slave Lake; 1944; ROM 13621.

333 *Hiodon tergisus* — 320 mm; Ontario, Norfolk Co., Lake Erie; Oct. 26, 1961; ROM 21638.

338 *Dallia pectoralis* — Male; 157 mm; Alaska, Koskokwim River; June 1956; ROM 18500.

341 *Umbra limi* — Female; 90 mm; Ontario, Peterborough Co., Connelly's Lake; Sept. 17, 1958; ROM 19830.

348 *Esox a. americanus* — Male; 190 mm; Quebec, Godfroy River.

352 *Esox a. vermiculatus* — Male; 219 mm; Ontario, Leeds Co., Jones Creek.

356 *Esox lucius* — Composite; 430 mm; 554 mm; Purchased; ROM 25777.

363 *Esox masquinongy* — Male; 663 mm; Ontario, Kenora Dist., Hogans' Pond; July 9, 1965; ROM 23575.

370 *Esox niger* — Female; 409 mm; Quebec, Lake Champlain; Apr. 8, 1967; ROM 25395.

386 *Acrocheilus alutaceus* — Male; 663 mm; British Columbia, Missizoula Lake; July 24–25, 1959; BC 60-221.

389 *Carassius auratus* — Composite; Ontario; ROM 15008 and 25405.

392 *Chrosomus eos* — 58.5 mm; Ontario, Timiskaming Dist., Jordan Lake; July 10, 1958; ROM 20030.

396 *Chrosomus neogaeus* — 65 mm; Ontario, Thunder Bay Dist., Pickerel Lake; July 20, 1964; ROM 23029.

399 *Clinostomus elongatus* — Female; 96 mm; Ontario, Lincoln Co., Twelve Mile Creek; Summer 1958; ROM 24663.

401 *Couesius plumbeus* — Female; 129 mm; Ontario, York Co., Mimico Creek; Apr. 6, 1951; ROM 14692.

407 *Cyprinus carpio* — Male; 245 mm; Ontario, York Co., Holland River; Summer 1965; ROM 24447.

412 *Exoglossum maxillingua* — Female; 84 mm; Ontario, Leeds Co., St. Lawrence River; Sept. 30, 1936; ROM 9213.

414 *Hybognathus hankinsoni* — 65 mm; Ontario, Grand River; June–July 1966; ROM 25228.

417 *Hybognathus nuchalis* — 123 mm; Ontario, Leeds Co.; June 13, 1967; ROM 25494.

420 *Hybopsis storeriana* — Female; 182 mm; Ontario, Norfolk Co., Lake Erie; June 13, 1946; ROM 18342.

423 *Hybopsis x-punctata* — 71 mm; Ontario, Thames River; Aug. 1958; ROM 20018.

424 *Mylocheilus caurinus* — Male; 238 mm; British Columbia, Thompson River; May 28, 1954; BC 54-78.

427 *Nocomis biguttatus* — Male; 119 mm; Ontario, Perth Co., Nith River; June 21–23, 1966; ROM 25088. Head, ROM 9214.

431 *Nocomis micropogon* — Male; 123 mm; Ontario, York Co., Humber River; Apr. 11, 1926; ROM N2454. Head, ROM 13263.

434 *Notemigonus crysoleucas* — Female; 95 mm; Ontario, Nipissing Dist., Costello Lake; June 3, 1937; ROM 19046.

438 *Notropis anogenus* — 40 mm; Ontario, Norfolk Co., Point Pelee National Park; ROM 14055.

440 *Notropis atherinoides* — 85 mm; Ontario, Manitoulin Island, Georgian Bay; May 13, 1968; ROM 25822.

444 *Notropis bifrenatus* — Female; 53 mm; New York, Thompkins Co., Fall Creek; Apr. 25–26, 1941; ROM 21671.

446 *Notropis blennius* — Female; 86 mm; Alberta, South Saskatchewan River; July 13, 1964; ROM 25923.

448 *Notropis cornutus* — Female; 134 mm; Ontario, Waterloo Co., Conestogo River; June 20, 1966; ROM 25175.

453 *Notropis emiliae* — 50 mm; Ontario, Thames River; Oct. 1968; ROM 26480.

454 *Notropis heterodon* — 53 mm; Ontario, Manitoulin Island, Wicket Lake; July 8, 1967; ROM 25868.

456 *Notropis heterolepis* — 65 mm; Ontario, Kenora Dist., Lake of the Woods; Summer 1963; ROM 23359.

459 *Notropis hudsonius* — Female; 98 mm; Ontario, Manitoulin Island, Georgian Bay; May 13, 1968; ROM 25820.

463 *Notropis rubellus* — 78 mm; Ontario, Haldimand Co., Grand River; June–July 1966; ROM 25205.

466 *Notropis spilopterus* — Male; 70 mm; Ontario, Leeds Co., St. Lawrence River; Aug. 29, 1959; ROM 23617.

469 *Notropis stramineus* — 65 mm; Ontario, Algoma Dist., Stokeley River; June 18, 1954; ROM 27054.

472 *Notropis umbratilis* — 50–54 mm; Ontario, Norfolk Co., Black Creek; July 25, 1947; ROM 18215.

473 *Notropis volucellus* — 62 mm; Quebec, Rivière Rigaud; Sept. 20, 1965; ROM 23984.

476 *Pimephales notatus* — Drawings by E. B. S. Logier, no data.

480 *Pimephales promelas* — Female; 67 mm; Ontario, Thunder Bay Dist., Pickerel River; June 8, 1964; ROM 23030.

484 *Platygobio gracilis* — Female; 275 mm; British Columbia, Fort Nelson River; Aug. 9, 1957; BC 57-224.

487 *Ptychocheilus oregonensis* — Male; 382 mm; British Columbia, Griffen Lake; Aug. 29, 1967; ROM 25555.

491 *Rhinichthys atratulus* — Male; 71 mm; Ontario, Northumberland Co., Shelter Valley Creek; July 20–21, 1966; ROM 25119.

494 *Rhinichthys cataractae* — Male; 86 mm; Ontario, Haldimand Co., Grand River; June–July 1966; ROM 25210.

498 *Rhinichthys falcatus* — Male; 74 mm; British Columbia, Chilcotin Dist., Nazko River; Aug. 15, 1956; ROM 18574.

501 *Rhinichthys osculus* — Female; 70 mm; British Columbia, Teslin Lake; July–Aug. 1944; ROM 18570.

503 *Richardsonius balteatus* — Female; 108 mm; British Columbia, Pothole Lake; ROM 25554.

507 *Semotilus atromaculatus* — Adult — male; 309 mm; Ontario, Haliburton Co., Big Straggle Lake; May 18, 1963; ROM 22323; Immature — 80 mm; Ontario, Renfrew Co., Chalk River; Aug. 11, 1966; ROM 24573.

511 *Semotilus corporalis* — Adult — composite ROM 12921 and ROM 24491; Immature — 78 mm; Ontario, Frontenac Co., Collins Creek; July 8, 1941; ROM 12921.

515 *Semotilus margarita* — Male; 135 mm; Ontario, Cochrane Dist., Munro Lake; July 30, 1958; ROM 20033.

528 *Carpiodes cyprinus* — Male; 390 mm; Ontario, Kent Co., Lake Erie; July 6, 1932; ROM 8056.

531 *Catostomus catostomus* — Male; 409 mm; Ontario, Bruce Co., Lake Huron; Apr. 5, 1968; ROM 25775.

536 *Catostomus columbianus* — Male; 126 mm; British Columbia, Cale Creek; Aug. 11, 1956; BC 56-570.

538 *Catostomus commersoni* — Female; 465 mm; New Brunswick, Carleton Co., Meduxnekeag River; May 25, 1958; ROM 19534.

544 *Catostomus macrocheilus* — Male; 413 mm; British Columbia, Wolfe Creek; May 16, 1956; BC 56-413.

547 *Catostomus platyrhynchus* — Male; 232 mm; Alberta, Cardston, Lee Creek; July 20, 1964; ROM 25919.

551 *Erimyzon sucetta* — Female; 270 mm; Ontario, Kent Co., Lake Erie; Apr. 12, 1955; ROM 17590.

554 *Hypentelium nigricans* — Male; 140 mm; Ontario, Peel Co., Credit River; Apr. 26, 1964; ROM 22766.

557 *Ictiobus cyprinellus* — Female; 315 mm and 355 mm; Saskatchewan, Last Mountain Lake; Feb. 5, 1955; ROM 16728.

564 *Moxostoma anisurum* — 354 mm; Ontario, Kent Co., Lake St. Clair; Feb. 19–May 20, 1964; ROM 22893.

567 *Moxostoma carinatum* — Female; 460 mm; Quebec, Lake St. Louis; 1941; ROM 13413.

571 *Moxostoma duquesnei* — Female; 329 mm; Michigan, Thornapple River; May 8–10, 1928; ROM 4463.

574 *Moxostoma erythrurum* — Female; 347 mm; Ontario, Elgin Co., Catfish Creek; Mar. 26, 1937; ROM 9633.

577 *Moxostoma hubbsi* — Male; 487 mm; Quebec, St. Hyacinthe, Yamaska River; Aug. 10–12, 1963; ROM 23118.

579 *Moxostoma macrolepidotum* — 386 mm; Ontario, Bruce Co., Lake Huron, Douglas Point; 1963; ROM 22509.

584 *Moxostoma valenciennesi* — Male; 393 mm; Ontario, Peel Co., Credit River; June 15, 1927; ROM 3552.

591 *Ictalurus melas* — Male; 196 mm; Saskatchewan, Souris River; Sept. 5, 1956; ROM 19948.

595 *Ictalurus natalis* — Male; 235 mm; Ontario, Norfolk Co., Lake Erie; Oct. 31, 1952; ROM 15633.

598 *Ictalurus nebulosus* — Male; 303 mm; Ontario, Muskoka Dist., Six Mile Lake; May 27, 1970; ROM 27094.

604 *Ictalurus punctatus* — Drawing by E. B. S. Logier, no data.

611 *Noturus flavus* — Female; 215 mm; Ontario, Durham Co., Wilmot Creek; Apr. 25, 1968; ROM 25813.

615 *Noturus gyrinus* — Female; 82 mm; Quebec, Napierville Co., Pond Southwest of Douglasburg; Apr. 22, 1969; ROM 27178.

619 *Noturus miurus* — Female; 86 mm; Ontario, Welland Co., Niagara River; 1958; ROM 20019.

624 *Anguilla rostrata* — Borrowed from FRB Bull. 155.

631 *Fundulus diaphanus* — Borrowed from FRB Bull. 155.

635 *Fundulus heteroclitus* — Borrowed from FRB Bull. 155.

641 *Lota lota* — Male; 510 mm; Ontario, Algonquin Park, Lake Opeongo; July 7, 1958; ROM 19838.

646 *Microgadus tomcod* — Borrowed from FRB Bull. 155.

652 *Labidesthes sicculus* — Male; 62 mm; Ontario, Frontenac Co., Lake Opinicon; ROM 23894.

658 *Apeltes quadracus* — Male; 42 mm; Newfoundland, Port au Port, Piccadilly Bay; July 14, 1960; ROM 20989.

661 *Culaea inconstans* — 48 mm; Ontario, Nipissing Dist., Aumond Creek; Aug. 8, 1966; ROM 24565.

665 *Gasterosteus aculeatus* — 52 mm; Newfoundland, Fortune Bay; July 26, 1960; ROM 21027.

669 *Gasterosteus wheatlandi* — 45 mm; Newfoundland, Port au Port; July 14, 1960; ROM 20988.

671 *Pungitius pungitius* — 66 mm; Ontario, Timiskaming Dist., Jerry Lake; Sept. 16, 1958; ROM 20026.

678 *Percopsis omiscomaycus* — Female; 106 mm; Ontario, Sudbury Dist., Spanish River; July 11, 1950; ROM 14958.

684 *Morone americana* — 255 mm; New Brunswick, St. John River; Nov. 15, 1968; ROM 26389.

689 *Morone chrysops* — 177 mm; Ontario, Norfolk Co., Lynn River; July 5, 1949; ROM 18328.

693 *Morone saxatilis* — 320 mm; Quebec, St. Lawrence River, May 1950; ROM 15983.

703 *Ambloplites rupestris* — Male; 173 mm; Ontario, Oxford Co., Nith River; June 21, 1966; ROM 25090.

707 *Lepomis auritus* — Male; 174 mm; New Brunswick, Kennebecasis River; Aug. 22, 1949; ROM 14587.

710 *Lepomis cyanellus* — Male; 135 mm; Ontario, Grey Co., Williams Lake; July 17, 1968; ROM 26098.

713 *Lepomis gibbosus* — Female; 165 mm; Ontario, Northumberland Co., Trent Canal; Aug. 20, 1958; ROM 19827.

719 *Lepomis macrochirus* — Male; 182 mm; Ontario, Frontenac Co., Rideau Canal; Apr. 28, 1968; ROM 25812.

724 *Lepomis megalotis* — Male; 96 mm; Ontario, Middlesex Co., Ausable River; June 30, 1969; ROM 26797.

728 *Micropterus dolomieui* — Male; 302 mm; Ontario, Peterborough Co., Connelly's Lake; Sept. 17, 1958; ROM 19836.

734 *Micropterus salmoides* — Female; 340 mm; Ontario, Leeds Co., St. Lawrence River; May 20, 1968; ROM 25886.

741 *Pomoxis annularis* — Male; 212 mm; Ontario, Essex Co., Cedar Creek; June 11, 1941; ROM 13214.

745 *Pomoxis nigromaculatus* — Female; 280 mm; Ontario, Ontario Co., Frenchman Bay; Apr. 15, 1958; ROM 20006.

755 *Perca flavescens* — Male; 225 mm; Ontario, Nipissing Dist., Aumond Creek; Aug. 10, 1966; ROM 24607.

762 *Stizostedion canadense* — Male; 325 mm; Ontario, Lake Erie; Nov., 1953; ROM 15970.

767 *Stizostedion vitreum* — Male; 392 mm; Ontario, Prince Edward Co., Lake Ontario; Nov. 16, 1957; ROM 18815.

775 *Ammocrypta pellucida* — Female; 60 mm; Ontario, Middlesex Co., Sydenham River; Sept. 9, 1927; ROM 3702.

777 *Etheostoma blennioides* — Male; 82 mm; Ontario, Peel Co., Thames River; Summer 1965; ROM 24485.

780 *Etheostoma caeruleum* — Male; 50 mm; Ontario, Ontario Co., Duffin Creek; ROM 24070.

783 *Etheostoma exile* — Female; 49 mm; Ontario, Manitoulin Island, Ice Lake; June 9, 1960; ROM 25853.

787 *Etheostoma flabellare* — Male; 62 mm; Ontario, Leeds Co., Jones Creek; June 4, 1960; ROM 21059.

790 *Etheostoma microperca* — 37 mm; Ontario, Bruce Co., Teeswater River; July 16, 1956; ROM 18515.

793 *Etheostoma nigrum* — Male; 61 mm; Manitoba, Valley River; Aug. 28, 1953; ROM 18456.

797 *Percina caprodes* — Female; 100 mm; Ontario, Algoma Dist., Harmony Creek; June 17, 1954; ROM 16241.

801 *Percina copelandi* — 41 mm; Ohio; ROM 6975.

803 *Percina maculata* — Male; 75 mm; Ontario, Oxford Co., Otter Creek; June–July 1967; ROM 26294.

806 *Percina shumardi* — 49 mm; Ontario, Kenora Dist., Sandy Lake; July 3–17, 1961; ROM 22373.

812 *Aplodinotus grunniens* — Male; 600 mm; Ontario, Leeds Co., St. Lawrence River; Aug. 20, 1967; ROM 25569.

820 *Cottus aleuticus* — Borrowed from FRB Bull. 173.

823 *Cottus asper* — Borrowed from FRB Bull. 173.

826 *Cottus bairdi* — Borrowed from the National Museum of Canada.

830 *Cottus cognatus* — Borrowed from the National Museum of Canada.

835 *Cottus confusus* — Borrowed from the Museum of Zoology, University of Michigan.

837 *Cottus rhotheus* — 47 mm; British Columbia, Kootenay River; Slocan Pool; June 20, 1928; ROM 6104.

839 *Cottus ricei* — Borrowed from FRB Bull. 173.

842 *Myoxocephalus quadricornis* — Drawing by E. B. S. Logier, no data.

THE ILLUSTRATORS . . .

Anker Odum, Scientific Illustrator in the Department of Entomology and Invertebrate Zoology, Royal Ontario Museum, prepared most of the pen-and-ink species illustrations as well as several of the paintings.

Peter Buerschaper is Chief Technician of the Department of Ichthyology and Herpetology at the Royal Ontario Museum. He prepared certain pen-and-ink drawings and colour illustrations of chars, painting used for the frontispiece, as well as the cover design of the book.

REFERENCES

REFERENCES

ADAMS, A. L. 1873. Field and forest rambles, with notes and observations on the natural history of eastern Canada. Henry S. King & Co., London. 333 p.

ADAMSTONE, F. B. 1922. Rates of growth of the blue and yellow pike perch. Univ. Toronto Stud. Publ. Ont. Fish. Res. Lab. 5: 77–86.

AGASSIZ, A. 1879. The development of *Lepidosteus*. Proc. Amer. Acad. Arts Sci. 1879, 14: 65–75.

AGASSIZ, J. L. R. 1848. Two new genera of fishes from Lake Superior, *Percopsis* and *Rhinichthys*. Proc. Boston Soc. Natur. Hist. 1848, 3: 80–81.

—— 1850. Lake Superior. Its physical character, vegetation, and animals, compared with those of other and similar regions. Gould, Kendall and Lincoln, Boston, Mass. 428 p.

—— 1855. Synopsis of the ichthyological fauna of the Pacific slope of North America, chiefly from the collections made by the expedition under the command of Capt. C. Wilkes, with recent additions and comparisons with eastern types. Amer. J. Sci. Arts, 2nd ser., 19(55): 71–99; 19(56): 215–232.

ALI, M. A., et M. ANCTIL. 1968. Corrélation entre la structure rétinienne et l'habitat chez *Stizostedion vitreum vitreum* et *S. canadense*. J. Fish. Res. Board Canada 25(9): 2001–2003.

ALI, M. A., and I. HANYU. 1964. Occurrence of multiple lenses in the eyes of brown bullheads (*Ictalurus nebulosus*). Copeia 1964(4): 704–705.

ALLIN, A. E. 1951. The fallfish, *Semotilus corporalis*, from the Lake Superior drainage of western Ontario. Copeia 1951(4): 300.

—— 1953. Records of the creek northern chub from Ontario. Can. Field-Natur. 67(3): 128–130.

AL-RAWI, A. H., and F. B. CROSS. 1964. Variation in the plains minnow, *Hybognathus placitus* Girard. Trans. Kansas Acad. Sci. 67(1): 154–168.

ALT, K. 1965. Food habits of inconnu in Alaska. Trans. Amer. Fish. Soc. 94(3): 272–274.

ANDREWS, A. K. 1970. Squamation chronology of the fathead minnow, *Pimephales promelas*. Trans. Amer. Fish. Soc. 99(2): 429–432.

ANDREWS, C. W. 1966. Landlocked Atlantic salmon (*Salmo salar* L.) in the Terra Nova River system, Newfoundland. Can. Field-Natur. 80(2): 101–109.

ANDREWS, C. W., and E. LEAR. 1956. The biology of Arctic char (*Salvelinus alpinus* L.) in northern Labrador. J. Fish. Res. Board Canada 13(6): 843–860.

ANONYMOUS. 1960. Maria eat eggs. Fishing. Fish. Br. Prov. Manitoba 1(4): 13.

—— 1964. Rough fish removal. Fishing. Fish. Br. Prov. Manitoba 4(1): 8–10.

APPELGET, J., and L. L. SMITH, JR. 1951. The determination of age and rate of growth from vertebrae of the channel catfish, *Ictalurus lacustris punctatus*. Trans. Amer. Fish. Soc. 80 (1950): 119–139.

APPLEGATE, V. C. 1943. Partial analysis of growth in a population of mudminnows, *Umbra limi* (Kirtland). Copeia 1943(2): 92–96.

—— 1950. Natural history of the sea lamprey, *Petromyzon marinus*, in Michigan. U.S. Fish Wildlife Serv. Spec. Sci. Rep. Fish. 55: 237 p.

APPLEGATE, V. C., and C. L. BRYNILDSON. 1952. Downstream movement of recently transformed sea lampreys, *Petromyzon marinus*, in the Carp Lake River, Michigan. Trans. Amer. Fish. Soc. 81 (1951): 275–290.

APPLEGATE, V. C., and M. L. H. THOMAS. 1965. Sex ratios and sexual dimorphism among recently transformed sea lampreys, *Petromyzon marinus* Linnaeus. J. Fish. Res. Board Canada 22(3): 695–711.

ARMSTRONG, R. H. 1965. Some migratory habits of the anadromous Dolly Varden *Salvelinus malma* (Walbaum) in southeastern Alaska. Alaska Dep. Fish Game Res. Rep. 3: 36 p.

ARMSTRONG, R. H., and W. M. MORTON. 1969. Revised annotated bibliography on the Dolly Varden char. Alaska Dep. Fish Game Res. Rep. 7: 108 p.

ARO, K. V., and M. P. SHEPARD. 1967. Salmon of the North Pacific Ocean — Part 4. Spawning populations of North Pacific salmon. 5. Pacific salmon in Canada. Int. North Pac. Fish. Comm. Bull. 23: 225–327.

ATTON, F. M. 1959. The invasion of Manitoba and Saskatchewan by carp. Trans. Amer. Fish. Soc. 88(3): 203–205.

ATTON, F. M., and R. P. JOHNSON. 1955. First records of eight species of fishes in Saskatchewan. Can. Field-Natur. 69(3): 82–84.

ATZ, J. W. 1940. Reproductive behavior in the eastern johnny darter, *Boleosoma nigrum olmstedi* (Storer). Copeia 1940(2): 100–106.

AYERS, H. D., H. R. MCCRIMMON, and A. H. BERST. 1963. Construction and management of farm ponds in Ontario. Ont. Dep. Agric. Publ. 515.

AYRES, W. O. 1854. (Description of new fishes from California). Proc. Calif. Acad. Natur. Sci., 1854–57 (1857), 1: 3–22.

—— 1855. (Description of *Petromyzon plumbeus*). Proc. Calif. Acad. Natur. Sci. 1: 28.

—— 1860. (On new fishes of the California coast). Proc. Calif. Acad. Sci. 1858–1862 (1863), 2: 52–64.

Babkin, B. P., and D. J. Bowie. 1928. The digestive system and its function in *Fundulus heteroclitus*. Biol. Bull. (Woods Hole) 54(3): 254–277.

Backus, R. H. 1951. New and rare records of fishes from Labrador. Copeia 1951(4): 288–294.

—— 1957. The fishes of Labrador. Bull. Amer. Mus. Natur. Hist. 113(4): 273–337.

Bailey, J. E. 1952. Life history and ecology of the sculpin *Cottus bairdi punctulatus* in southwestern Montana. Copeia 1952(4): 243–255.

Bailey, M. M. 1963. Age, growth, and maturity of round whitefish of the Apostle Islands and Isle Royale regions, Lake Superior. U.S. Fish Wildlife Serv. Fish. Bull. 63(1): 63–75.

—— 1964. Age, growth, maturity, and sex composition of the American smelt, *Osmerus mordax* (Mitchill), of western Lake Superior. Trans. Amer. Fish. Soc. 93(3): 382–395.

Bailey, R. M. 1938. The fishes of the Merrimack watershed, p. 149–185. *In* Biological survey of the Merrimack watershed. N. H. Fish Game Dep. Survey Rep. 3.

—— 1941. The scientific name of the black crappie. Copeia 1941(1): 21–23.

—— 1951. A check-list of the fishes of Iowa, with keys for identification, p. 185–237 + 9 figs. *In* Iowa Fish and Fishing, by James R. Harlan and Everett B. Speaker. Iowa State Conserv. Comm., Des Moines, Iowa. 237 p.

—— 1954. Distribution of the American cyprinid fish *Hybognathus hankinsoni* with comments on its original description. Copeia 1954(4): 289–291.

—— 1956. A revised list of the fishes of Iowa with keys for identification, p. 327–377 + 10 figs. *In* Iowa Fish and Fishing, 3rd ed., by James R. Harlan and Everett B. Speaker. Iowa State Conserv. Comm., Des Moines, Iowa. 377 p.

—— 1959. Distribution of the American cyprinid fish *Notropis anogenus*. Copeia 1959(2): 119–123.

Bailey, R. M., and M. O. Allum. 1962. Fishes of South Dakota. Misc. Publ. Mus. Zool. Univ. Mich. 119: 131 p + 1 pl.

Bailey, R. M., and C. E. Bond. 1963. Four new species of freshwater sculpins, genus *Cottus*, from western North America. Occas. Pap. Mus. Zool. Univ. Mich. 634: 27 p.

Bailey, R. M., and M. F. Dimick. 1949. *Cottus hubbsi*, a new cottid fish from the Columbia River system in Washington and Idaho. Occas. Pap. Mus. Zool. Univ. Mich. 513: 18 p.

Bailey, R. M., J. E. Fitch, E. S. Herald, E. A. Lachner, C. C. Lindsey, C. R. Robins, and W. B. Scott. 1970. A list of common and scientific names of fishes from the United States and Canada. 3rd ed. Amer. Fish. Soc. Spec. Publ. 6: 150 p. Ann Arbor, Mich.

Bailey, R. M., and C. R. Gilbert. 1960. The American cyprinid fish *Notropis kanawha* identified as an interspecific hybrid. Copeia 1960(4): 354–357.

Bailey, R. M., and H. M. Harrison, Jr. 1948. Food habits of the southern channel catfish (*Ictalurus lacustris punctatus*) in the Des Moines River, Iowa. Trans. Amer. Fish. Soc. 75 (1945): 110–138.

Bailey, R. M., and C. L. Hubbs. 1949. The black basses (*Micropterus*) of Florida, with description of a new species. Occas. Pap. Mus. Zool. Univ. Mich. 516: 40 p. + 2 pl.

Bailey, R. M., E. A. Lachner, C. C. Lindsey, C. R. Robins, P. M. Roedel, W. B. Scott, and L. P. Woods. 1960. A list of common and scientific names of fishes from the United States and Canada. 2nd ed. Amer. Fish. Soc. Spec. Publ. 2: 102 p. Ann Arbor, Mich.

Bailey, R. M., and K. F. Lagler. 1938. An analysis of hybridization in population of stunted sunfishes in New York. Pap. Mich. Acad. Sci. Arts Lett. 23 (1937): 577–606.

Bailey, R. M., H. E. Winn, and C. L. Smith. 1954. Fishes from the Escambia River, Alabama and Florida, with ecologic and taxonomic notes. Proc. Acad. Natur. Sci. Philadelphia 106: 109–164 + 1 fig.

Bajkov, A. 1927. Reports of the Jasper Park Lakes investigation, 1925–26. I. The fishes. Contrib. Can. Biol. Fish. n.s. 3(16): 379–404.

—— 1928. A preliminary report on the fishes of the Hudson Bay drainage system. Can. Field-Natur. 42(4): 96–99.

—— 1930. Fishing industry and fisheries investigations in the Prairie Provinces. Trans. Amer. Fish. Soc. 60 (1930): 215–237.

Baker, F. C. 1916. The relation of mollusks to fish in Oneida Lake. N.Y. Coll. Forestry, Syracuse Univ. Tech. Publ. 4: 1–366 + figs. 1–49.

Baldwin, N. S. MS 1948. A study of the speckled trout *Salvelinus fontinalis* (Mitchill) in a pre-Cambrian lake. M.A. Thesis. Univ. Toronto, Toronto, Ont. 53 p. + 1 table.

—— 1950. The American smelt, *Osmerus mordax* (Mitchill), of South Bay, Manitoulin Island, Lake Huron. Trans. Amer. Fish. Soc. 78 (1948): 176–180.

—— 1957. Food consumption and growth of brook trout at different temperatures. Trans. Amer. Fish. Soc. 86 (1956): 323–328.

Baldwin, N. S., and R. W. Saalfeld. 1962. Commercial fish production in the Great Lakes, 1867–1960. Great Lakes Fish. Comm. Tech. Rep. 3: 166 p.

Bănărescu, P. 1964. Fauna republicii populare Romîne, vol. 13. Academia Republicii Populare Romîne, Bucuresti. 959 p.

Bangham, R. V. 1940. Parasites of fish of Algonquin Park lakes. Progr. Fish-Cult. Memo. I–131(52): 37.

—— 1941. Parasites of fish of Algonquin Park lakes. Trans. Amer. Fish. Soc. 70 (1940): 161–171.

—— 1955. Studies on fish parasites of Lake Huron and Manitoulin Island. Amer. Midland Natur. 53(1): 184–194.

Bangham, R. V., and J. R. Adams. 1954. A survey of the parasites of freshwater fishes from the mainland of British Columbia. J. Fish. Res. Board Canada 11(6): 673–708.

Bangham, R. V., and G. W. Hunter III. 1936. Studies of fish parasites of Lake Erie. III. *Microcotyle spinicirrus* MacCallum (1918) char. emend. and *M. eriensis* sp.nov. Trans. Amer. Microsc. Soc. 55(3): 334–339.

—— 1939. Studies on fish parasites of Lake Erie. Distribution studies. Zoologica 24(4); pt. 27: 385–448.

Bangham, R. V., and C. E. Venard. 1946. Parasites of fish of Algonquin Park lakes. Univ. Toronto Stud. Biol. Ser. 53, Publ. Ont. Fish. Res. Lab. 65: 33–46.

Bardach, J. E., J. H. Todd, and R. Crickmer. 1967. Orientation by taste in fish of the genus *Ictalurus*. Science 155(3767): 1276–1278.

Bardack, D., and R. Zangerl. 1968. First fossil lamprey: a record from the Pennsylvanian of Illinois. Science 162(3859): 1265–1267.

Barney, R. L. 1926. The distribution of the fresh-water sheepshead, *Aplodinotus grunniens* Rafinesque, in respect to the glacial history of North America. Ecology 7(3): 351–364.

Barraclough, W. E. 1964. Contribution to the marine life history of the eulachon *Thaleichthys pacificus*. J. Fish. Res. Board Canada 21(5): 1333–1337.

Battle, H. I. 1940. The embryology and larval developments of the goldfish (*Carassius auratus* L.) from Lake Erie. Ohio J. Sci. 40(2): 82–93.

Battle, H. I., and W. M. Sprules. 1960. A description of the semi-buoyant eggs and early developmental stages of the goldeye, *Hiodon alosoides* (Rafinesque). J. Fish. Res. Board Canada 17(2): 245–265.

Beamish, R. J. MS 1970. Factors affecting the age and size of the white sucker, *Catostomus commersoni*, at maturity. Ph.D. Thesis. Dep. Zool. Univ. Toronto, Toronto, Ont.

Beamish, R. J., and H. H. Harvey. 1969. Age determination in the white sucker. J. Fish. Res. Board Canada 26(3): 633–638.

Bean, T. H. 1879. Fishes collected in Cumberland Gulf and Disko Bay. Bull. U.S. Nat. Mus. 15: 107–138.

—— 1880a. Description of an apparently new species of *Gasterosteus* (*G. Atkinsii*) from the Schoodic Lakes, Maine. Proc. U.S. Nat. Mus. (1879) 2: 67–79.

—— 1880b. Descriptions of some genera and species of Alaskan fishes. Proc. U.S. Nat. Mus. (1879) 2: 353–359.

—— 1882. Descriptions of new fishes from Alaska and Siberia. Proc. U.S. Nat. Mus. (1881) 4: 144–159.

—— 1884a. On the occurrence of branch alewife in certain lakes of New York. Fish. and Fish. Ind. of U.S. by G. B. Goode, sec. 1: 588–593.

—— 1884b. Notes on a collection of fishes made in 1882 and 1883 by Capt. Henry E. Nichols, U.S.N., in Alaska and British Columbia, with a description of a new genus and species, *Prionistius macellus*. Proc. U.S. Mus. 6(23): 353–367.

—— 1887. Description of a supposed new species of char (*Salvelinus aureolus*) from Sunapee Lake, New Hampshire. Proc. U.S. Nat. Mus. 10: 628–630.

—— 1889. Description of *Coregonus pusillus*, a new species of whitefish from Alaska. Proc. U.S. Nat. Mus. 11: 526.

—— 1891. Kennerly's salmon. Trans. Amer. Fish. Soc. 20 (1891): 41–46.

—— 1894a. Life history of the salmon. Bull. U.S. Fish Comm. (1892) 12: 21–38.

—— 1894b. Bibliography of the salmon of Alaska and adjacent regions. Bull. U.S. Fish Comm. (1892) 12: 39–49.

—— 1903a. The food and game fishes of New York: notes on their common names, distribution, habits and mode of capture. State N.Y. Forest Fish Game Comm. p. 251–460.

—— 1903b. Catalogue of the fishes of New York. N.Y. State Mus. Bull. 60: 784 p.

—— 1916. Description of a new cisco from Lake Erie. Proc. Biol. Soc. Washington 29: 25–26.

Becker, C. D. 1962. A new haemogregarine from the blood of a freshwater fish, *Catostomus macrocheilus* Girard. J. Parasitol. 48(4): 596–600.

Beckman, W. C. 1949. The rate of growth and sex ratio for seven Michigan fishes. Trans. Amer. Fish. Soc. 76 (1946): 63–81.

Behnke, R. J. 1966. Relationships of the far eastern trout, *Salmo mykiss* Walbaum. Copeia 1966(2): 346–348.

Belding, D. L. 1939. The number of eggs and pyloric appendages as criteria of river varieties of the Atlantic salmon (*Salmo salar*). Trans. Amer. Fish. Soc. 69 (1939): 285–289.

Bell, J. M., and C. Thompson. 1951. Freshwater fish as an ingredient of mink rations. Fish. Res. Board Canada Bull. 92: 13 p.

Bell, R. 1880. Report on explorations on the Churchill and Nelson Rivers and around God's and Island Lakes, 1879. Geol. Surv. Can. Progr. Rep. 1878–79, part C. 72 p.

Bendire, C. 1882. Notes on Salmonidae of the upper Columbia. Proc. U.S. Nat. Mus. (1881) 4: 81–87.

Bennett, G. W. 1954. Largemouth bass in Ridge Lake, Coles County, Illinois. Ill. Natur. Hist. Surv. Bull. 26(2): 217–275.

Bensley, B. A. 1915. Fishes of Georgian Bay. Contrib. Can. Biol. Sess. Pap. 39b (1911–14): 1–51.

Berg, L. S. 1909. Ichthyologia amurensis. Mem. Acad. Sci. 8, ser. 24: 1–270. St. Petersburg.

—— 1931. A review of the lampreys of the northern hemisphere. Akad. Nauk SSSR Zool. Mus. Ann. 32: 87–116 + 8 pls. Leningrad.

—— 1932. Les poissons des eaux douces de l'U.R.S.S. et des pays limitrophes. 3rd ed. L'Inst. Pêches Pisciculture, Leningrad. vol. 1: 543 p. (In Russian)

—— 1936. Note on *Coregonus* (*Prosopium*) *cylindraceus* (Pallas). Copeia 1936(1): 57–58.

—— 1940. Classification of fishes, both recent and fossil. Trav. de l'Inst. Zool. de l'Acad. des Sci. de l'URSS 5(2): 87–517. Repr. 1965, App. Sci. Res. Corp. Thailand. 304 p. (English)

—— 1948. Freshwater fishes of the U.S.S.R. and adjacent countries. Akad. Nauk SSSR Zool. Inst., vol. 1, 4th ed. 493 p. + App. (Translation by Israel Program for Scientific Translations, 1962)

Berry, F. H. 1955. Food of the mudfish (*Amia calva*) in Lake Newnan, Florida, in relation to its management. Quart. J. Florida Acad. Sci. 18(1): 69–75.

Bersamin, S. V. 1958. A preliminary study of the nutritional ecology and food habits of the chubs (*Leucichthys* spp.) and their relation to the ecology of Lake Michigan. Pap. Mich. Acad. Sci. Arts Lett. 43: 107–118.

Bertrand, E. 1893. Observations sur divers modes de reproduction chez les poissons. Bull. Soc. Centr. Aquicult. France 5: 115–119.

Beverton, R. J. H., and S. J. Holt. 1959. A review of the lifespans and mortality rates of fish in nature, and their relation to growth and other physiological characteristics, p. 142–180. *In* G. E. W. Wolstenholme and M. O'Connor [ed.], Ciba Foundation Colloquia on Ageing, vol. 5. The lifespan of animals. Little, Brown and Co., Boston. 324 p. + 46 pls.

Beyerle, G. B., and E. L. Cooper. 1960. Growth of brown trout in selected Pennsylvania streams. Trans. Amer. Fish. Soc. 89(3): 255–262.

Bicknell, E. P., and F. B. Dresslar. 1886. A review of the species of the genus *Semotilus*. Proc. Acad. Natur. Sci. Philadelphia (1885): 14–18.

Bidgood, B. F., and A. H. Berst. 1967. Phenotypic characteristics of rainbow trout in the Great Lakes. J. Fish. Res. Board Canada 24(4): 887–892.

Bigelow, H. B. 1963. *Salvelinus fontinalis*, p. 525–542. *In* Fishes of the western North Atlantic. Mem. Sears Found. Mar. Res. 1(3): 630 p.

Bigelow, H. B., and W. C. Schroeder. 1948. Fishes of the western North Atlantic (lancelets, cyclostomes and sharks). Mem. Sears Found. Mar. Res. 1(1): 576 p.

—— 1953. Fishes of the Gulf of Maine. U.S. Fish Wildlife Serv. Fish. Bull. 74, Vol. 53: 577 p.

—— 1963. Family Osmeridae. p. 533–597. *In* Fishes of the western North Atlantic. Mem. Sears Found. Mar. Res. 1(3): 630 p.

Bigelow, N. K. 1923. The food of young suckers (*Catostomus commersonii*) in Lake Nipigon. Univ. Toronto Stud. Biol. Ser. 24, Publ. Ont. Fish. Res. Lab. 21: 83–115.

Bilton, H. T., D. W. Jenkinson, and M. P. Shepard. 1964. A key to five species of Pacific salmon (genus *Oncorhynchus*) based on scale characters. J. Fish. Res. Board Canada 21(5): 1267–1288.

Bilton, T. H., and M. P. Shepard. 1955. The sports fishery for cut-throat trout at Lakelse Lake, British Columbia. Fish. Res. Board Canada Progr. Rep. Pac. 104: 38–42.

Birman, I. B. 1950. Parasitism of salmon of the genus *Oncorhynchus* by the Pacific lamprey. Izvestiia TINRO 32: 158–160. (Fish. Res. Board Canada Translation 290, 1960)

Bishop, F. G. 1971. Observations on spawning habits and fecundity of Arctic grayling. Progr. Fish-Cult. 33(1): 12–19.

Bishop, S. C. 1946. An alleged new species of muskellunge. Copeia 1946(1): 43.

Bissett, E. D. R. 1927. Fresh-water fish of Manitoba. Can. Field-Natur. 41(6): 127–128.

Bjorn, E. E. 1940. Preliminary observations and experimental study of the ling, *Lota maculosa*, in Wyoming. Trans. Amer. Fish. Soc. 69 (1939): 192–196.

Black, E. C. 1953. Upper lethal temperatures of some British Columbia freshwater fishes. J. Fish. Res. Board Canada 10(4): 196–210.

Black, J. D. 1945. Natural history of the northern mimic shiner, *Notropis volucellus volucellus* Cope. Invest. Indiana Lakes Streams 2(18): 449–469.

Black, R. D. 1934. Charles Fothergill's notes on the natural history of eastern Canada, 1816–1837. Trans. Roy. Can. Inst. 20(1): 141–168.

Black, V. S. 1945. Gas exchange in the swimbladder of the mudminnow. Proc. Nova Scotian Inst. Sci. 21 (1 and 2): 1–22.

Blackett, R. F. 1962. Some phases in the life history of the Alaskan blackfish, *Dallia pectoralis*. Copeia 1962(1): 124–130.

—— 1968. Spawning behavior, fecundity and early life history of anadromous Dolly Varden in southeastern Alaska. Alaska Dep. Fish Game Res. Rep. 6: 85 p.

Bleakney, S. 1954. Food habits of lake trout from Squaw Lake, northern Quebec. Can. Field-Natur. 68(2): 94.

Bodola, A. 1966. Life history of the gizzard shad, *Dorosoma cepedianum* (LeSueur), in western Lake Erie. U.S. Fish Wildlife Serv. Fish. Bull. 65(2): 391–425.

Bonn, E. W. 1953. The food and growth rate of young white bass (*Morone chrysops*) in Lake Texoma. Trans. Amer. Fish. Soc. 82 (1952): 213–221.

Booke, H. E. 1968. Cytotaxonomic studies of the coregonine fishes of the Great Lakes, USA: DNA and karyotype analysis. J. Fish. Res. Board Canada 25(8): 1667–1687.

Boulva, J., et A. Simard. 1968. Présence du *Salvelinus namaycush* (Pisces: Salmonidae) dans les eaux marines de l'Arctique occidental canadien. J. Fish. Res. Board Canada 25(7): 1501–1504.

Bowen, E. S. 1931. The role of the sense organs in aggregations of *Ameiurus melas*. Ecol. Monogr. 1: 1–35.

—— 1932. Further studies of the aggregating behavior of *Ameiurus melas*. Biol. Bull. (Woods Hole) 63(2): 258–270.

Bowman, M. L. 1970. Life history of the black redhorse, *Moxostoma duquesnei* (Lesueur), in Missouri. Trans. Amer. Fish. Soc. 99(3): 546–559.

Boyd, J. W., and N. Tomlinson. 1965. Myxosporidian parasite from salmon. J. Fish. Res. Board Canada 22(3): 849–850.

Branion, H. 1930. The marketing of the ling (burbot). Trans. Amer. Fish. Soc. 60: 199–203.

Bratzler, L. J., and M. O. Robinson. 1967. Processing Great Lakes chub (*Leucichthys hoyi*). Quart. Bull. Mich. Agric. Exp. Sta. Mich. State Univ. 49(4): 440–444.

Breder, C. M., Jr. 1928. On the appetite of *Amiatus calva* (Linnaeus). Copeia (1928)167: 54–56.

—— 1936a. "All modern conveniences." A note on the nest architecture of the four-spined stickleback. Bull. N.Y. Zool. Soc. 39(2): 72–76.

—— 1936b. I. The reproductive habits of the North American sunfishes (family Centrarchidae). Zoologica 21(1): 1–48 + 1 pl.

—— 1940. The nesting behavior of *Eupomotis gibbosus* (Linnaeus) in a small pool. Zoologica 25(3): 353–360 + 2 pls.

Breder, C. M., Jr., and R. J. Nigrelli. 1935. The influence of temperature and other factors on the winter aggregations of the sunfish, *Lepomis auritus*, with critical remarks on the social behavior of fishes. Ecology 16(1): 33–47.

Breder, C. M., Jr., and D. E. Rosen. 1966. Modes of reproduction in fishes. Natur. Hist. Press, New York, N.Y. 941 p.

Brett, J. R. 1952. Temperature tolerance in young Pacific salmon, genus *Oncorhynchus*. J. Fish. Res. Board Canada 9(6): 265–323.

Brett, J. R., and D. B. Sutherland. 1965. Respiratory metabolism of pumpkinseed (*Lepomis gibbosus*) in relation to swimming speed. J. Fish. Res. Board Canada 22(2): 405–409.

Brown, C. J. D. 1952. Spawning habits and early development of the mountain whitefish, *Prosopium williamsoni*, in Montana. Copeia 1952(2): 109–113.

Brown, C. J. D., and J. W. Moffett. 1942. Observations on the number of eggs and feeding habits of the cisco (*Leucichthys artedi*) in Swains Lake, Jackson County, Michigan. Copeia 1942(3): 149–152.

Brown, E. H., Jr. 1970. Extreme female predominance in the bloater (*Coregonus hoyi*) of Lake Michigan in the 1960's, p. 501–514. *In* C. C. Lindsey and C. S. Woods [ed.] Biology of coregonid fishes. Univ. Manitoba Press, Winnipeg, Man. 560 p.

Brown, M. E. 1957a. The physiology of fishes. Vol. 1. Metabolism. Academic Press Inc., New York, N.Y. 447 p.

—— 1957b. The physiology of fishes. Vol. 2. Behavior. Academic Press Inc., New York, N.Y. 526 p.

Bruemmer, F. 1967. Eeling in Quebec. Can. Audubon 29(1): 11–14.

Brummett, A. R. 1966. Observations on the eggs and breeding season of *Fundulus heteroclitus* at Beaufort, North Carolina. Copeia 1966(3): 616–620.

Bryan, C. F. 1969. Variation in selected meristic characters of some basses, *Micropterus*. Copeia 1969(2): 370–374.

Brynildson, O. M., V. A. Haker, and T. A. Klick. 1963. Brown trout. Its life history, ecology and management. Wis. Conserv. Dep. Publ. 234: 14 p.

Buchwald, D. G. MS 1968. The Arctic lamprey of Great Slave Lake, N.W.T. M.Sc. Thesis. Univ. Alberta, Edmonton, Alta. 84 p.

Buchwald, D. G., and J. R. Nursall. 1969. *Triaenophorus crassus* in Arctic lampreys of the Northwest Territories, Canada. J. Fish. Res. Board Canada 26(8): 2260–2261.

Budd, J. (C.) 1957a. Introduction of the hybrid between the eastern brook trout and lake trout into the Great Lakes. Can. Fish Cult. 20: 25–28.

—— 1957b. Movements of tagged whitefish in northern Lake Huron and Georgian Bay. Trans. Amer. Fish. Soc. 86 (1956): 128–134.

—— 1959. The use of the hybrid between eastern brook trout and lake trout in fishery management. Trans. N.E. Wildlife Conf. 10: 115–116.

—— MS 1961. The use of the South Bay creel census in understanding the smallmouth bass fishery and predicting its course. Ont. Dep. Lands Forests Res. Br. South Bay Mouth, Ont. 9 p.

Budde, W. 1965. Candling for the detection of *Triaenophorus crassus* cysts in whitefish. J. Fish. Res. Board Canada 22(3): 865–867.

Bulkley, R. V. 1960. Use of branchiostegal rays to determine age of lake trout, *Salvelinus namaycush* (Walbaum). Trans. Amer. Fish. Soc. 89(4): 344–350.

—— 1961. Fluctuations in age composition and growth rate of cutthroat trout in Yellowstone Lake. U.S. Fish Wildlife Serv. Bur. Sport Fish. Wildlife Res. Rep. 54: 31 p.

Buller, F. 1971. Pike. Macdonald, London. 320 p.

Burdick, G. E., E. J. Harris, H. J. Dean, T. M. Walker, J. Skea, and D. Colby. 1964. The accumulation of DDT in lake trout and the effect on reproduction. Trans. Amer. Fish. Soc. 93(2): 127–136.

Burner, C. J. 1951. Characteristics of spawning nests of Columbia River salmon. U.S. Fish Wildlife Serv. Fish. Bull. 61, Vol. 52: 97–110.

Buss, K. 1957. The controversial kokanee — a salmon for the lakes of northeastern United States. Pa. Fish Comm. Spec. Purpose Rep. 13 p.

—— 1961. The northern pike. Pa. Fish Comm. Benner Spring Fish Res. Sta. Spec. Sci. Rep. 58 p. (Mimeo.)

—— 1962. A literature survey of the life history of the redfin and grass pickerels. Pa. Fish Comm. Benner Spring Fish Res. Sta. 12 p. (Mimeo.)

Buss, K., and J. E. Wright, Jr. 1956. Results of species hybridization within the family Salmonidae. Progr. Fish-Cult. 18(4): 149–158.

—— 1958. Appearance and fertility of trout hybrids. Trans. Amer. Fish. Soc. 87 (1957): 172–181.

Bykovskaya-Pavlovskaya, I. E., et al. 1962. Key to parasites of freshwater fish of the USSR. Zool. Inst. Acad. Sci. U.S.S.R. (English transl. TT 64-11040, OTS, Dep. Comm. Washington, D.C. 919 p.)

Cahn, A. R. 1927. An ecological study of southern Wisconsin fishes. Ill. Biol. Monogr. 11(1): 1–151.

Cameron, G. S. 1948. An unusual maskinonge from Little Vermilion Lake, Ontario. Can. J. Res., D, 26: 223–229.

Campbell, R. S. MS 1935. A study of the common sucker, *Catostomus commersoni* (Lacépède), of Waskesiu Lake. M.A. Thesis. Dep. Biol. Univ. Saskatchewan, Saskatoon, Sask. 48 p.

Carbine, W. F. 1939. Observations on the spawning habits of centrarchid fishes in Deep Lake, Oakland County, Michigan. Trans. 4th N.A. Wildlife Conf. p. 275–287.

Carl, G. C. 1936. Food of the coarse-scaled sucker (*Catostomus macrocheilus* Girard). J. Biol. Board Canada 3(1): 20–25.

—— 1938. A spawning run of brown trout in the Cowichan river system. Fish. Res. Board Canada Progr. Rep. Pac. 36: 12–13.

—— 1953. Limnobiology of Cowichan Lake, British Columbia. J. Fish. Res. Board Canada 9(9): 417–449.

Carl, G. C., and W. A. Clemens. 1948. The fresh-water fishes of British Columbia. B.C. Prov. Mus. Handb. 5: 132 p.

—— 1953. The fresh-water fishes of British Columbia. 2nd ed. (rev.). B.C. Prov. Mus. Handb. 5: 136 p.

Carl, G. C., W. A. Clemens, and C. C. Lindsey. 1967. The fresh-water fishes of British Columbia. B.C. Prov. Mus. Handb. 5: 192 p.

Carlander, K. D. 1941. The darters (Etheostominae) of Minnesota. Proc. Minn. Acad. Sci. 9: 41–48.

—— 1945. Growth length–weight relationship and population fluctuations of the tullibee, *Leucichthys artedi tullibee* (Richardson), with reference to the commercial fisheries, Lake of the Woods, Minnesota. Trans. Amer. Fish. Soc. 73 (1943): 125–136.

—— 1950a. Handbook of freshwater fishery biology. Wm. C. Brown Co., Dubuque, Iowa. 281 p.

—— 1950b. Growth rate studies of saugers, *Stizostedion canadense canadense* (Smith) and yellow perch, *Perca flavescens* (Mitchill) from Lake of the Woods, Minnesota. Trans. Amer. Fish. Soc. 79 (1949): 30–42.

—— 1953. Handbook of freshwater fishery biology with the first supplement. Wm. C. Brown Co., Dubuque, Iowa. 430 p.

—— 1969. Handbook of freshwater fishery biology. Vol. 1. Life history data on freshwater fishes of the United States and Canada, exclusive of the Perciformes. Iowa State Univ. Press. Ames, Iowa. 752 p.

Carlson, D. R. 1967. Fathead minnow, *Pimephales promelas* Rafinesque, in the Des Moines River. Boone County, Iowa, and the Skunk River drainage, Hamilton and Story counties, Iowa. Iowa State J. Sci. 41(3): 363–374.

Carr, M. H. 1942. The breeding habits, embryology and larval development of the large-mouthed black bass in Florida. Proc. New England Zool. Club 20: 43–77.

Carter, A. H. MS 1940. Life history and ecology of the minnow, *Nocomis biguttatus* (Kirtland). M.A. Thesis. Univ. Toronto, Toronto, Ont.

Cartier, D., et É. Magnin. 1967. La croissance en longueur et en poids des *Amia calva* L. de la région de Montréal. Can. J. Zool. 45(5): 797–804.

Cartwright, J. W. 1961. Investigation of the rainbow trout of Kootenay Lake, British Columbia, with special reference to the Lardeau River. Brit. Columbia Fish Game Br. Manage. Publ. 7: 46 p.

Carufel, L. H. 1963. Life history of saugers in Garrison Reservoir. J. Wildlife Manage. 27(3): 450–456.

Casselman, J. M. MS 1967. Age and growth of northern pike, *Esox lucius* Linnaeus, in the upper St. Lawrence River. M.Sc. Thesis. Dep. Zool. Univ. Guelph, Guelph, Ont. 219 p.

Cating, J. P. 1953. Determining age of Atlantic shad from their scales. U.S. Fish Wildlife Serv. Fish. Bull. 85, Vol. 54: 187–199.

Catt, J. 1949. Small-mouthed black bass in the waters of New Brunswick and Nova Scotia. Can. Fish Cult. 4(5): 15–18.

—— 1950. Some notes on brown trout with particular reference to their status in New Brunswick and Nova Scotia. Can. Fish Cult. 7: 25–27.

Chadwick, H. K. 1959. California sturgeon tagging studies. Calif. Fish Game 45(4): 297–301.

Chambers, K. J. 1963. Lake of the Woods survey. Northern sector — 1963. (Preliminary report.) Ont. Dep. Lands Forests, Maple, Ont. 65 p.

—— 1966. Winter angling for Sabaskong crappies. Ont. Fish Wildlife Rev. Dep. Lands Forests 5(1): 3–5.

Chapman, W. M. 1934. The osteology of the haplimous fish *Novumbra hubbsi* Schultz with comparative notes on related species. J. Morphol. 56(2): 371–405.

—— 1939. Eleven new species and three new genera of oceanic fishes collected by the International Fisheries Commission from the northeastern Pacific. Proc. U.S. Nat. Mus. 86: 501–542.

Chatwin, B. M. 1953. Age and size of chum salmon from the Johnstone Strait area. Fish. Res. Board Canada Progr. Rep. Pac. 97: 9–10.

Cheek, R. P. 1968. The American shad. U.S. Fish Wildlife Serv. Fish. Leafl. 614: 13 p.

Chidester, F. E. 1916. A biological study of the more important of the fish enemies of the salt marsh mosquitoes. Bull. N.J. Agric. Exp. Sta. New Brunswick 300: 1–16.

Chlebeck, A., and G. L. Phillips. 1969. Hematological study of two buffalofishes, *Ictiobus cyprinellus* and *I. bubalus* (Catostomidae). J. Fish. Res. Board Canada 26(11): 2881–2886.

Choquette, L. P. E. 1948. Parasites of freshwater fish. IV. Internal helminths parasitic in speckled trout (*Salvelinus fontinalis* (Mitchill)) in rivers and lakes of the Laurentide Park, Quebec, Canada. Can. J. Res., D, 26: 204–211.

—— 1955. The life history of the nematode *Metabronema salvelini* (Fujita, 1920) parasitic in the speckled trout, *Salvelinus fontinalis* (Mitchill), in Quebec. Can. J. Zool. 33(1): 1–4.

Christie, W. J. 1960. Variation in vertebral count in F_2 hybrids of *Salvelinus fontinalis* × *S. namaycush*. Can. Fish Cult. 26: 15–21.

—— 1963. Effects of artificial propagation and the weather on recruitment in the Lake Ontario whitefish fishery. J. Fish. Res. Board Canada 20(3): 597–646.

Clady, M. D. 1967. Changes in an exploited population of the cisco, *Coregonus artedii* LeSueur. Pap. Mich. Acad. Sci. Arts Lett. 52: 85–99.

Clemens, H. P. 1951a. The food of the burbot, *Lota lota maculosa* (LeSueur) in Lake Erie. Trans. Amer. Fish. Soc. 80 (1950): 56–66.

—— 1951b. The growth of the burbot, *Lota lota maculosa* (LeSueur) in Lake Erie. Trans. Amer. Fish. Soc. 80 (1950): 163–173.

Clemens, H. P., and K. E. Sneed. 1957. The spawning behavior of the channel catfish *Ictalurus punctatus*. U.S. Fish Wildlife Serv. Spec. Sci. Rep. Fish. 219: 11 p.

Clemens, W. A. 1939. The fishes of Okanagan Lake and nearby waters, p. 27–38. *In* A biological survey of Okanagan Lake, British Columbia. Fish. Res. Board Canada Bull. 56: 70 p.

—— 1953. On some fundamental problems in the biology of Pacific salmon. Trans. Roy. Soc. Canada 47 ser. 3, sec. 5: 1–13.

Clemens, W. A., R. V. Boughton, and J. A. Rattenbury. 1945. A preliminary report on a fishery survey of Teslin Lake, British Columbia. Rep. Prov. Fish. Dep. for year 1944, Prov. B.C.: M70–M73.

Clemens, W. A., J. R. Dymond, and N. K. Bigelow. 1924. Food studies of Lake Nipigon fishes. Univ. Toronto Stud. Biol. Ser. 25, Publ. Ont. Fish. Res. Lab. 25: 101–165.

Clemens, W. A., J. R. Dymond, N. K. Bigelow, F. B. Adamstone, and W. J. K. Harkness. 1923. The food of Lake Nipigon fishes. Univ. Toronto Stud. 22, Publ. Ont. Fish. Res. Lab. 16: 171–188.

Clemens, W. A., and J. A. Munro. 1934. The food of the squawfish. Fish. Res. Board Canada Progr. Rep. Pac. 19: 3–4.

Clemens, W. A., D. S. Rawson, and J. L. McHugh. 1939. A biological survey of Okanagan Lake, British Columbia. Fish. Res. Board Canada Bull. 56: 70 p.

Clemens, W. A., and G. V. Wilby. 1946. Fishes of the Pacific coast of Canada. Fish. Res. Board Canada Bull. 68: 368 p.

—— 1961. Fishes of the Pacific coast of Canada. 2nd ed. Fish. Res. Board Canada Bull. 68: 443 p.

Clinton, DeWitt. 1824. Description of a new species of fish from the Hudson river (*Clupea hudsonia*). Ann. Lyceum Natur. Hist. N.Y. 1: 49–50.

Coble, D. W. 1966. Dependence of total annual growth in yellow perch on temperature. J. Fish. Res. Board Canada 23(1): 15–20.

—— 1967. Relationship of temperature to total annual growth in adult smallmouth bass. J. Fish. Res. Board Canada 24(1): 87–99.

Cockerell, T. D. A. 1909. The nomenclature of the American fishes usually called *Leuciscus* and *Rutilus*. Proc. Biol. Soc. Washington 22: 215–218.

—— 1913. Observations on fish scales. Bull. Bur. Fish. (1912) 32 (doc. 779): 117–174 + pls. 32–40.

Cohen, D. M. 1954. Age and growth studies on two species of whitefishes from Point Barrow, Alaska. Stanford Ichthyol. Bull. 4(3): 168–187.

Colby, P. J., and L. T. Brooke. 1970. Survival and development of lake herring (*Coregonus artedii*) eggs at various incubation temperatures, p. 417–428. *In* C. C. Lindsey and C. S. Woods [ed.] Biology of coregonid fishes. Univ. Manitoba Press, Winnipeg, Man. 560 p.

Cole, C. F. 1965. Additional evidence for separation of *Etheostoma olmstedi* Storer from *Etheostoma nigrum* Rafinesque. Copeia 1965(1): 8–13.

—— 1967. A study of the eastern Johnny darter, *Etheostoma olmstedi* Storer (Teleostei, Percidae). Chesapeake Sci. 8(1): 28–51.

Collette, B. B., and L. W. Knapp. 1966. Catalog of type specimens of the darters (Pisces, Percidae, Etheostomatini). Proc. U.S. Nat. Mus. 119(3550): 88 p.

Cook, F. R. 1961. Further records of the eastern blacknose dace in Nova Scotia. Can. Field-Natur. 75(1): 51–52.

Cooper, A. R. 1915. Contributions to the life history of *Proteocephalus ambloplitis* Leidy. A parasite of the black bass. Contrib. Can. Biol. 1911–1914 (2): 177–194.

—— 1918. North American pseudophyllidean cestodes. Ill. Biol. Monogr. 4(4): 291–531.

Cooper, E. L. 1952. Returns from plantings of legal-sized brook, brown and rainbow trout in the Pigeon River, Otsego County, Michigan. Trans. Amer. Fish. Soc. 82 (1952): 265–280.

—— 1953. Growth of brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) in the Pigeon River, Otsego County, Michigan. Pap. Mich. Acad. Sci. Arts Lett. 38: 151–162.

—— 1959. Trout stocking as an aid to fish management. Pennsylvania Agric. Exp. Sta. Bull. 663: 21 p.

—— 1970. Growth of cutthroat trout (*Salmo clarki*) in Chef Creek, Vancouver Island, British Columbia. J. Fish. Res. Board Canada 27(11): 2063–2070.

Cooper, G. P. 1935. Some results of forage fish investigations in Michigan. Trans. Amer. Fish. Soc. 65 (1935): 132–142.

—— 1936a. Importance of forage fishes. Proc. First N. Amer. Wildlife Conf. p. 305–310.

—— 1936b. Age and growth of the golden shiner (*Notemigonus crysoleucas auratus*) and its suitability for propagation. Pap. Mich. Acad. Sci. Arts Lett. 21: 587–597.

—— 1937. Food habits, rate of growth and cannibalism of young largemouth bass (*Aplites salmoides*) in State-operated rearing ponds in Michigan during 1935. Trans. Amer. Fish. Soc. 66 (1936): 242–266.

—— 1940. A biological survey of the Rangeley Lakes with special reference to the trout and salmon. Maine Dep. Inland Fish. Game Fish Surv. Rep. 3.

—— 1941. A biological survey of lakes and ponds of the Androscoggin and Kennebec River drainage systems in Maine. Maine Dep. Inland Fish. Game Fish. Surv. Rep. 4: 228 p. + 25 pls.

Cooper, G. P., and R. N. Schafer. 1954. Studies on the population of legal-size fish in Whitmore Lake, Washtenaw and Livingstone Counties, Michigan. Trans. N. Amer. Wildlife Conf. 19: 239–258.

Coots, M. 1955. The Pacific lamprey, *Entosphenus tridentatus*, above Copco Dam, Siskiyou County, California. Calif. Fish Game 41(1): 118–119.

Cope, E. D. 1862. (Observations upon certain cyprinoid fish in Pennsylvania.) Proc. Acad. Natur. Sci. Philadelphia (1861): 522–524.

—— 1864. Partial catalogue of the cold-blooded vertebrata of Michigan. Pt. I. Proc. Acad. Natur. Sci. Philadelphia 16: 276–285.

—— 1865. Partial catalogue of the cold-blooded vertebrata of Michigan. Part II. Proc. Acad. Natur. Sci. Philadelphia 17: 78–88.

—— 1869. Synopsis of the Cyprinidae of Pennsylvania. Trans. Amer. Phil. Soc. 13(2): 351–399, 4 pls. + figs.

—— 1870. Partial synopsis of the freshwater fishes of North Carolina. Proc. Amer. Phil. Soc. 11: 448–495.

—— 1872. Recent reptiles and fishes. Report on the reptiles and fishes obtained by the naturalists of the expedition, p. 432–443. *In* Part IV: Special Reports *of* Preliminary Report of the U.S. Geol. Survey of Wyoming and portions of contiguous territories, by F. V. Hayden. 511 p.

—— 1873. On the extinct vertebrata of the Eocene of Wyoming, p. 545–649. *In* United States Geological Survey Territories embracing portions of Montana, Idaho, Wyoming and Utah; being a report of progress of the explorations for the year 1872 (Hayden) Sixth Ann. Rep. xi + 844 p.

Cope, O. B. 1964. Revised bibliography on the cutthroat trout. U.S. Fish Wildlife Serv. Bur. Sport Fish. Wildlife Res. Rep. 65: 43 p.

Cox, Philip. 1893. Observations on the distribution and habits of some New Brunswick fishes. Bull. Natur. Hist. Soc. New Brunswick 3(2): 33–42.

—— 1896a. History and present state of the ichthyology of New Brunswick. Bull. Natur. Hist. Soc. New Brunswick 13: 27–61.

—— 1896b. Catalogue of the marine and freshwater fishes of New Brunswick. Bull. Natur. Hist. Soc. New Brunswick 13: 62–75.

—— 1899. Fresh water fishes and batrachia of the Peninsula of Gaspé, P.Q., and their distribution in the Maritime Provinces of Canada. Trans. Roy. Soc. Canada ser. 2, 5, sec. 4: 141–154.

—— 1901. Cyprinidae of eastern Canada. Proc. Natur. Hist. Assoc. Miramichi 2: 36–45. World Press, Chatham, N.B.

—— 1921. A cyprinid new to science. Can. Field-Natur. 35(4): 66–67.

—— 1922. Results of the Hudson Bay Expedition, 1920. II. The Gasterosteidae. Contrib. Can. Biol. (1921) 10: 149–153.

—— 1923. A new stickleback from the west coast of Newfoundland. Can. Field-Natur. 37(8): 147–148.

—— 1924. New and rare records of certain freshwater fishes in Canada. Can. Field-Natur. 38(5): 85–86.

Cox, U. O. 1896. A report upon the fishes of southwestern Minnesota. Rep. U.S. Fish Comm. (1894) 20: 605–616.

—— 1897. A preliminary report on the fishes of Minnesota. Geol. Natur. Hist. Surv. Minn., (Zool.) 3: i–x, 1–93, 1 pl.

Coyle, E. E. 1930. The algal food of *Pimephales promelas* (fathead minnow). Ohio J. Sci. 30(1): 23–35.

Creaser, C. W. 1925. The establishment of the Atlantic smelt in the upper waters of the Great Lakes. Pap. Mich. Acad. Sci. Arts Lett. 5: 405–423, fig. 25, pls. 24–27.

—— 1927. The food of the yearling smelt from Michigan. Pap. Mich. Acad. Sci. Arts Lett. 10: 427–431.

Creaser, C. W., and C. S. Hann. 1929. The food of larval lampreys. Pap. Mich. Acad. Sci. Arts Lett. 10: 433–437.

Creaser, C. W., and C. L. Hubbs. 1922. A revision of the holarctic lampreys. Occas. Pap. Mus. Zool. Univ. Mich. 120: 14 p. + 1 pl.

Cross, F. B. 1967. Handbook of fishes of Kansas. Univ. Kansas Mus. Natur. Hist. Misc. Publ. 45: 357 p.

Crossman, E. J. 1959a. Distribution and movements of a predator, the rainbow trout, and its prey, the redside shiner, in Paul Lake, British Columbia. J. Fish. Res. Board Canada 16(3): 247–267.

—— 1959b. A predator–prey interaction in freshwater fish. J. Fish. Res. Board Canada 16(3): 269–281.

—— 1960. Variation in number and asymmetry in branchiostegal rays in the family Esocidae. Can. J. Zool. 38(2): 363–375.

—— 1962a. The grass pickerel, *Esox americanus vermiculatus* LeSueur, in Canada. Roy. Ont. Mus. Univ. Toronto, Life Sci. Div. Contrib. 55: 29 p.

—— 1962b. Predator–prey relationships in pikes (Esocidae). J. Fish. Res. Board Canada 19(5): 979–980.

—— 1962c. The redfin pickerel, *Esox a. americanus* in North Carolina. Copeia 1962(1): 114–123.

—— 1962d. Black spot parasite in fishes. Inform. Leafl. Dep. Ichth. Herpetol. Roy. Ont. Mus. April. 4 p. + refs.

—— 1962e. A colour mutant of the yellow perch from Lake Erie. Can. Field-Natur. 76(4): 224–225.

—— 1966. A taxonomic study of *Esox americanus* and its subspecies in eastern North America. Copeia 1966(1): 1–20.

Crossman, E. J., and K. Buss. 1965. Hybridization in the family Esocidae. J. Fish. Res. Board Canada 22(5): 1261–1292.

—— 1966. Artificial hybrid between kokanee (*Oncorhynchus nerka*) and brook trout (*Salvelinus fontinalis*). Copeia 1966(2): 357–359.

Crossman, E. J., and R. G. Ferguson. 1963. The first record from Canada of *Minytrema melanops*, the spotted sucker. Copeia 1963(1): 186–187.

Crossman, E. J., and P. A. Larkin. 1959. Yearling liberations and change of food as effecting rainbow trout yield in Paul Lake, British Columbia. Trans. Amer. Fish. Soc. 88 (1959): 36–44.

Crowe, W. R. 1962. Homing behavior in walleyes. Trans. Amer. Fish. Soc. 91(4): 350–354.

Cucin, D., and H. A. Regier. 1965. Dynamics and exploitation of lake whitefish in southern Georgian Bay. J. Fish. Res. Board Canada 23(2): 221–274.

Cuerrier, J.-P. 1943. Résultats de l'étiquetage d'achigans pratiqué dans la Rivière Châteauguay, à Châteauguay, Québec, depuis 1941. Rev. Can. Biol. 2(5): 545–548.

—— 1947. *Esox americanus* in Quebec. Copeia 1947(1): 62.

—— 1949. L'esturgeon de lac: âge croissance, maturité. Chasse et Pêche (6).

Cuerrier, J.-P., F. E. J. Fry, et G. Prefontaine. 1946. Liste préliminaire des poissons de la région de Montréal et du Lac Saint-Pierre. Natur. Can. 73: 17–32.

Cuerrier, J.-P., and F. H. Schultz. 1957. Studies of lake trout and common whitefish in Waterton Lakes, Waterton Lakes National Park, Alberta. Wildlife Manage. Bull. (Ottawa) ser. 3, 5: 1–41.

Curran, H. W., J. Bardach, R. I. Bowman, and H. G. Lawler. 1947. A biological survey of Lake Opinicon. Progr. Rep. Queen's Univ. Biol. Sta. Chaffey's Lock, Ont. 48 p.

Cuvier, G. A., et M. A. Valenciennes. 1828–1849. Histoire naturelle des poissons. Levrault, Strasborg. 22 vol. Paris.

Cuvier, G. L. C. F. D. 1834. The animal kingdom arranged in conformity with its organization, with supplementary additions to each order, by Edward Griffith. Vol. 10. The class Pisces arranged by the Baron Cuvier with supplementary additions, by Edward Griffith and Charles Hamilton Smith. Whittaker & Co. London. i–viii + 680 p.

Daiber, F. C. 1952. The food and feeding relationships of the freshwater drum, *Aplodinotus grunniens* Rafinesque in western Lake Erie. Ohio J. Sci. 52(1): 35–46.

—— 1953. Notes on the spawning population of the freshwater drum (*Aplodinotus grunniens* Rafinesque) in western Lake Erie. Amer. Midland Natur. 50(1): 159–171.

—— 1956. A comparative analysis of the winter feeding habits of two benthic stream fishes. Copeia 1956(3): 141–151.

Dall, W. H. 1870. Alaska and its resources. Boston, Mass. 628 p.

(Dall, W. H.) 1871. The food fishes of Alaska. Rep. U.S. Comm. Agric. for 1870: 375–392. (No author's name with paper, but credited to Dall by editor on p. 154.)

Darnell, R. M., and R. R. Meierotto. 1965. Diurnal periodicity in the black bullhead, *Ictalurus melas* (Rafinesque). Trans. Amer. Fish. Soc. 94(1): 1–8.

Davidson, F. A., and S. J. Hutchinson. 1938. The geographic distribution and environmental limitations of the Pacific salmon (genus *Oncorhynchus*). Bull. Bur. Fish. 48(26): 667–692.

Davidson, V. M. MS 1949. Fish (salmon) management. Fish. Res. Board Canada. MS Rep. Biol. Sta. 401: 15–20.

—— MS 1950. Fish (salmon) management. Fish. Res. Board Canada. MS Rep. Biol. Sta. 427: 30–39.

—— MS 1951. Fish (salmon) management. Fish. Res. Board Canada. MS Rep. Biol. Sta. 498: 74–79.

Davis, B. J., and R. J. Miller. 1967. Brain patterns in minnows of the genus *Hybopsis* in relation to feeding habits and habitat. Copeia 1967(1): 1–39.

Davis, C. C. 1959. A planktonic fish egg from fresh water. Limnol. Oceanogr. 4(3): 352–355.

Davis, H. S. 1953. Culture and diseases of game fishes. Univ. Calif. Press, Berkeley and Los Angeles, Calif. 332 p.

Davis, W. S. 1957. Ova production of American shad in Atlantic coast rivers. U.S. Fish Wildlife Serv. Res. Rep. 49: 5 p.

Dawson, J. W. 1859. On a new species of stickleback (*Gasterosteus gymnetes*). Can. Natur. Geol. 4(5), art. 24: 321–324.

Day, Francis. 1880–1884. The fishes of Great Britian and Ireland. Vol. 2. Williams and Norgate, London. 388 p. + pls.

Dean, B., and F. B. Sumner. 1897. Notes on the spawning habits of the brook lamprey (*Petromyzon wilderi*). Trans. N.Y. Acad. Sci. 16(2): 321–324.

Deason, H. J. 1939. The distribution of cottid fishes in Lake Michigan. Pap. Mich. Acad. Sci. Arts Lett. 24(2): 105–115.

Deason, H. J., and R. Hile. 1947. Age and growth of the kiyi, *Leucichthys kiyi* Koelz, in Lake Michigan. Trans. Amer. Fish. Soc. 74 (1944): 88–142.

Dechtiar, A. O. 1965. Preliminary observations on *Glugea hertwigi*, Weissenberg, 1911 (Microsporidia; Glugeidae) in American smelt, *Osmerus mordax* (Mitchill) from Lake Erie. Can. Fish Cult. 34: 35–38.

—— 1966a. A new species of *Phyllodistomum* (Trematoda: Gorgoderidae) from *Coregonus clupeaformis* (Mitchill) from Lake of the Woods (Ontario). Can. J. Zool. 44(1): 135–140.

—— 1966b. A new species of monogenetic trematode, *Octomacrum semotili*, from the creek chub, *Semotilus atromaculatus* (Mitchill) from Algonquin Park lakes. Can. J. Zool. 44(5): 821–824.

—— 1967a. *Neoechinorhynchus notemigoni* n.sp. (Acanthocephala: Neoechinorhynchidae) from golden shiner of Lake Ontario. Can. J. Zool. 45(2): 155–159.

—— 1967b. *Neodiscocotyle carpioditis* n.gen., n.sp., monogenetic trematode (Discocotylidae: Neodiscocotylinae subfam. n.) from the gills of the quillback, *Carpiodes cyprinus* (Le Sueur) of Lake Erie. Can. J. Zool. 45(4): 473–478.

—— 1968. *Neoechinorhynchus carpiodi* n.sp. (Acanthocephala: Neoechinorhynchidae) from quillback of Lake Erie. Can. J. Zool. 46(2): 201–204.

—— 1969. Two new species of monogenetic trematodes (Trematoda: Monogenea) from nasal cavities of catostomid fishes. J. Fish. Res. Board Canada 26(4): 865–869.

Dechtiar, A. O., and K. H. Loftus. 1965. Two new hosts for *Cyathocephalus truncatus* (Pallas, 1781) (Cestoda: Cyathocephalidae) in Lake Huron. Can. J. Zool. 43(2): 407–408.

DeKay, J. E. 1842. Natural history of New York. Part I. Zoology. Reptiles and fishes. Part 4 — Fishes. Appleton and Co., and Wilby and Putnam, Albany, N.Y. 415 p.

DeLacy, A. C., and W. M. Morton. 1943. Taxonomy and habits of the charrs, *Salvelinus malma* and *Salvelinus alpinus*, of the Karluk drainage system. Trans. Amer. Fish. Soc. 72 (1942): 79–82.

Delisle, C. 1969. Bimonthly progress of a non-lethal infection by *Glugea hertwigi* in young-of-the-year smelt, *Osmerus eperlanus mordax*. Can. J. Zool. 47(5): 871–876.

Delisle, C., and W. Van Vliet. 1968. First records of the sculpins *Myoxocephalus thompsonii* and *Cottus ricei* from the Ottawa Valley, southwestern Quebec. J. Fish. Res. Board Canada 25(12): 2733–2737.

Delisle, C., et C. Veilleux. 1969. Répartition géographique de l'éparlan arc-en-ciel *Osmerus eperlanus mordax* et de *Glugea hertwigi* (Sporozoa: Microsporidia) en eau douce, au Québec. Natur. Can. 96: 337–358.

Dence, W. A. 1948. Life history, ecology and habits of the dwarf sucker, *Catostomus commersonnii utawana* Mather, at the Huntington Wildlife Station. Roosevelt Wildlife Bull. 8(4): 81–150.

—— 1952. Establishment of white perch, *Morone americana*, in central New York. Copeia 1952(3): 200–201.

—— 1958. Studies on *Ligula*-infected common shiners (*Notropis cornutus frontalis* Agassiz) in the Adirondacks. J. Parasitol. 44(3): 334–338.

Denny, M. 1938. The lateral-line system of the teleost, *Fundulus heteroclitus*. J. Comp. Neurol. 68(1): 49–65.

De Roth, G. C. 1963. Age and growth studies of channel catfish in western Lake Erie. J. Wildlife Manage. 29(2): 280–286.

Desrocher, J. E. 1904. Poisson-castor. Natur. Can. 11: 38.

Dimick, R. E., and D. C. Mote. 1934. A preliminary survey of the food of Oregon trout. Oregon State Coll. Agric. Exp. Sta. Bull. 323: 23 p.

Disler, N. N. 1953. Ecological and morphological characteristics of the development of the Amur autumn chum salmon — *Oncorhynchus keta* Walbaum. Akad. Nauk SSSR, Ikhtiol. Kom. Trudy Sov. 1: 354–362.

Doan, K. H. 1938. Observations on dogfish (*Amia calva*) and their young. Copeia 1938(4): 204.

—— 1939. Growth of bass fry. Copeia 1939(2): 81–87.

—— 1940. Studies of the smallmouth bass. J. Wildlife Manage. 4(3): 241–266.

—— 1941. Relation of sauger catch to turbidity in Lake Erie. Ohio J. Sci. 41(6): 449–452.

Dobie, J. 1959. Note on food of northern log perch. Trans. Amer. Fish. Soc. 88(3): 213.

Dobie, J., O. L. Meehean, S. F. Snieszko, and G. N. Washburn. 1956. Raising bait fishes. U.S. Fish Wildlife Serv. Circ. 35: 123 p.

Dobie, J. R., O. L. Meehean, and G. N. Washburn. 1948. Propagation of minnows and other bait species. U.S. Fish Wildlife Serv. Circ. 12: 113 p.

Dodge, D. P., and H. R. MacCrimmon. 1970. Vital statistics of a population of Great Lakes rainbow trout (*Salmo gairdneri*) characterized by an extended spawning season. J. Fish. Res. Board Canada 27(3): 613–618.

Dombroski, E. 1955. Cestode and nematode infection of sockeye smolts from Babine Lake, British Columbia. J. Fish. Res. Board Canada 12(1): 93–96.

Dresel, H. G. 1884. Notes on some Greenland fishes. Proc. U.S. Nat. Mus. 7: 244–258.

Driver, E. A., and E. T. Garside. 1966. Meristic numbers of yellow perch in saline lakes in Manitoba. J. Fish. Res. Board Canada 23(11): 1815–1817.

Dryer, W. R. 1963. Age and growth of the whitefish in Lake Superior. U.S. Fish Wildlife Serv. Fish. Bull. 63(1): 77–95.

—— 1966. Bathymetric distribution of fish in the Apostle Islands region, Lake Superior. Trans. Amer. Fish. Soc. 95(3): 248–259.

Dryer, W. R., and J. Beil. 1964. Life history of lake herring in Lake Superior. U.S. Fish Wildlife Serv. Fish. Bull. 63(3): 493–530.

—— 1968. Growth changes of the bloater (*Coregonus hoyi*) of the Apostle Islands region of Lake Superior. Trans. Amer. Fish. Soc. 97(2): 146–158.

Dryer, W. R., L. F. Erkkila, and C. L. Tetzloff. 1965. Food of lake trout in Lake Superior. Trans. Amer. Fish. Soc. 94(2): 169–176.

Dryfoos, R. L. 1961. Four range extensions of fishes from the northeastern Pacific. Copeia 1961(4): 476–477.

Dubois, A., and R. Lagueux. 1968. Etude comparée de l'âge scalaire et de l'âge otolithique de la touladi (*Salvelinus namaycush*), Lac Mistassini, Québec. Natur. Can. 95(4): 907–928.

Duméril, August. 1870. Histoire naturelle des poissons ou ichthyologie générale 2: 624 p.

Dunbar, M. J., and H. H. Hildebrand. 1952. Contribution to the study of the fishes of Ungava Bay. J. Fish. Res. Board Canada 9(2): 83–128.

D'Urban, W. S. M. 1859. Observations on the natural history of the valley of the River Rouge, and surrounding townships in the counties of Argenteuil and Ottawa. Can. Natur. Geol. 4: 252–276.

Dymond, J. R. 1922. A provisional list of the fishes of Lake Erie. Univ. Toronto Stud. Biol. Ser. 20, Publ. Ont. Fish. Res. Lab. 4: 57–73.

—— 1926. The fishes of Lake Nipigon. Univ. Toronto Stud. Biol. Ser. 27, Publ. Ont. Fish. Res. Lab. 27: 1–108.

—— 1928a. A description of *Leucichthys tullibee* (Richardson) based on six specimens from the type locality. Univ. Toronto Stud. Biol. Ser. 31, Publ. Ont. Fish. Res. Lab. 31: 1–6.

—— 1928b. Some factors affecting the production of lake trout (*Cristivomer namaycush*) in Lake Ontario. Univ. Toronto Stud. Biol. Ser. 31, Publ. Ont. Fish. Res. Lab. 33: 27–41.

—— 1931a. The small-mouthed black bass and its conservation. Ont. Dep. Game Fish., Biol. Fish Cult. Br. Bull. 2: 10 p.

—— 1931b. Description of two new forms of British Columbia trout. Contrib. Can. Biol. Fish. n.s. 6(16): 393–395.

—— 1932a. Records of the alewife and steelhead (rainbow) trout from Lake Erie. Copeia (1932)1: 32–33.

—— 1932b. Blue perch. Copeia 1932(4): 182.

—— 1932c. The trout and other game fishes of British Columbia. Dep. Fish. Ottawa, Ont. 51 p.

—— 1933. The coregonine fishes of Hudson and James bays. *In* Biological and oceanographic conditions in Hudson Bay. Contrib. Can. Biol. Fish. 8(1) (Ser. A, Gen. 28): 1–12.

—— 1936. Some fresh-water fishes of British Columbia. Rep. Comm. Fish. for British Columbia (1935). Contrib. Roy. Ont. Mus. Zool. 9: L60–L73.

—— 1937. New records of Ontario fishes. Copeia (1937)1: 59.

—— 1939. The fishes of the Ottawa region. Contrib. Roy. Ont. Mus. Zool. 15: 1–43.

—— 1943. The coregonine fishes of northwestern Canada. Trans. Roy. Can. Inst. 24(2): 171–231.

—— 1944a. Spread of the smelt (*Osmerus mordax*) in the Canadian waters of the Great Lakes. Can. Field-Natur. 58(1): 12–14.

—— 1944b. Distribution of the cyprinid fishes, *N. deliciosus* and *N. volucellus* in Ontario. Can. Field-Natur. 58(6): 195.

—— 1947. A list of the freshwater fishes of Canada east of the Rocky Mountains, with keys. Roy. Ont. Mus. Zool. Misc. Publ. 1: 36 p.

—— 1955. The introduction of foreign fishes into Canada. Proc. Int. Assoc. Theor. Appl. Limnol. 12: 543–553.

—— 1957. Artificial propagation in the management of Great Lakes fisheries. Trans. Amer. Fish. Soc. 86 (1956): 384–392.

—— 1963. Family Salmonidae, p. 457–502. *In* Fishes of the western North Atlantic. Mem. Sears Found. Mar. Res. 1(3): 630 p.

—— 1964. A history of ichthyology in Canada. Copeia 1964(1): 2–33.

Dymond, J. R., and J. L. Hart. 1927. The fishes of Lake Abitibi (Ontario) and adjacent waters. Univ. Toronto Stud. Biol. Ser., Publ. Ont. Fish. Res. Lab. 28: 1–19.

Dymond, J. R., J. L. Hart, and A. L. Pritchard. 1929. The fishes of the Canadian waters of Lake Ontario. Univ. Toronto Stud. Biol. Ser. 33, Publ. Ont. Fish. Res. Lab. 37: 1–35.

Dymond, J. R., and A. L. Pritchard. 1930. Some ciscoes or lake herrings of western Canada. Contrib. Can. Biol. Fish. n.s. 5(17): 467–474.

Dymond, J. R., and W. B. Scott. 1941. Fishes of Patricia Portion of the Kenora District, Ontario. Copeia 1941(4): 243–245.

Dymond, J. R., and V. D. Vladykov. 1934. The distribution and relationship of the salmonoid fishes of North America and North Asia. Proc. 5th Pac. Sci. Congress 5: 3741–3750.

Eales, J. G. 1968. The eel fisheries of eastern Canada. Fish. Res. Board Canada Bull. 166: 79 p.

Eddy, S., and T. Surber. 1960. Northern fishes with special reference to the upper Mississippi Valley. Rev. ed. Charles T. Branford Co., Mass. 276 p.

Edsall, T. A. 1960. Age and growth of the whitefish, *Coregonus clupeaformis*, of Munising Bay, Lake Superior. Trans. Amer. Fish. Soc. 89(4): 323–332.

—— 1967. Biology of the freshwater drum in western Lake Erie. Ohio J. Sci. 67(6): 321–340.

Edsall, T. A., and P. J. Colby. 1970. Temperature tolerance of young-of-the-year cisco, *Coregonus artedii*. Trans. Amer. Fish. Soc. 99(3): 526–531.

Ege, V. 1939. A revision of the genus *Anguilla* Shaw. A systematic, phylogenetic and geographical study. Dana-Report 16: 256 p. + 53 figs. and charts, + 6 pls.

Ehrenbaum, E. 1894. Beitrage zur Naturgeschichte einiger Elbfische (*Osmerus eperlanus* L., *Clupea finta* Cuv., *Acerina cernua* L., *Acipenser sturio* L.). Beilage zu den "Mittheilungen des deutschen Seefischereivereins," Nr. 10: 49 p. + 4 pls. Berlin.

Eigenmann, C. H. 1895. Results of explorations in western Canada and the northwestern United States. Bull. U.S. Fish Comm. (1894) 14: 101–132.

Eigenmann, C. H., and R. S. Eigenmann. 1892. New fishes from western Canada. Amer. Natur. 26: 961–964.

—— 1893a. Preliminary descriptions of new fishes from the Northwest. Amer. Natur. 27: 151–154.

—— 1893b. Scientific news. Amer. Natur. 27(318): 592.

Eigenmann, C. R., and C. H. Kennedy. 1902. The leptocephalus of the American eel and other American *Leptocephali*. Bull. U.S. Fish Comm. (1901) 21: 81–92.

Eipper, A. W. 1964. Growth, mortality rates, and standing crops of trout in New York farm ponds. Cornell Exp. Sta. Memoir 388: 67 p.

Ellis, D. V., and M. A. Giles. 1965. The spawning behavior of the walleye, *Stizostedion vitreum* (Mitchill). Trans. Amer. Fish. Soc. 94(4): 358–362.

Ellis, M. M., and G. C. Roe. 1917. Destruction of log perch eggs by suckers. Copeia 1917(47): 69–71.

Emery, A. R. 1970. Fish and crayfish mortalities due to an internal seiche in Georgian Bay, Lake Huron. J. Fish. Res. Board Canada 27(6): 1165–1168.

Emig, J. W. 1966. Brown bullhead, p. 463–475. *In* Inland Fisheries Management. Calif. Dep. Fish Game Resources Agency.

English, T. S. 1952. A method of sectioning carp spines for growth studies. Progr. Fish-Cult. 14(1): 36.

Eschmeyer, P. H. 1955. The reproduction of lake trout in southern Lake Superior. Trans. Amer. Fish. Soc. 84 (1954): 47–74.

Eschmeyer, P. H., and R. M. Bailey. 1955. The pygmy whitefish, *Coregonus coulteri*, in Lake Superior. Trans. Amer. Fish. Soc. 84 (1954): 161–199.

Eschmeyer, P. H., and A. M. Phillips, Jr. 1965. Fat content of the flesh of siscowets and lake trout from Lake Superior. Trans. Amer. Fish. Soc. 94(1): 62–74.

Evans, H. E. 1952. The correlation of brain pattern and feeding habits in four species of cyprinid fishes. J. Compar. Neurol. 97(1): 133–142.

Evans, H. E., and E. E. Deubler, Jr. 1955. Pharyngeal tooth replacement in *Semotilus atromaculatus* and *Clinostomus elongatus*, two species of cyprinid fishes. Copeia 1955(1): 31–41.

Everhart, W. H. 1958. Fishes of Maine. Maine Dep. Inland Fish. Game: 1–94.

Everhart, W. H., and C. A. Waters. 1965. Life history of the blueback trout (Arctic char, *Salvelinus alpinus* (Linnaeus)) in Maine. Trans. Amer. Fish. Soc. 94(4): 393–397.

Evermann, B. W. 1893. A reconnaissance of the streams and lakes of western Montana and northwestern Wyoming. Bull. U.S. Fish Comm. (1891) 11: 3–60.

Evermann, B. W., and H. W. Clark. 1920. Lake Maxinkuckee: a physical and biological survey. Indiana Dep. Conserv. 1: 1–660.

Evermann, B. W., and T. D. Cockerell. 1909. Descriptions of three new species of cyprinoid fishes. Proc. Biol. Soc. Washington 22: 185–188.

Evermann, B. W., and U. O. Cox. 1896. Report upon the fishes of the Missouri river basin. Rep. U.S. Fish Comm. (1894) 20: 325–429.

Evermann, B. W., and E. L. Goldsborough. 1907a. A check list of the freshwater fishes of Canada. Proc. Biol. Soc. Washington 20: 89–119.

—— 1907b. The fishes of Alaska. Bull. Bur. Fish. (1906) 26: 219–360.

Evermann, B. W., and W. C. Kendall. 1901. Notes on the fishes of Lake Ontario. N.Y. Forest Fish Game Comm. Ann. Rep. (1900): 479–488.

—— 1902. Notes on the fishes of Lake Ontario. Rep. U.S. Comm. Fish Fish. (1901) 27: 209–216.

Evermann, B. W., and H. B. Latimer. 1910. The fishes of the Lake of the Woods and connecting waters. Proc. U.S. Nat. Mus. 39: 121–136.

Evermann, B. W., and H. M. Smith. 1896. The whitefishes of North America. Rep. U.S. Fish Comm. (1894) 20: 283–324 + 18 pls.

Ewers, L. A. 1933. Summary report of Crustacea used as food by the fishes of the western end of Lake Erie. Trans. Amer. Fish. Soc. 63 (1933): 379–390.

Eycleshymer, A. C. 1901. Observations on the breeding habits of *Ameiurus nebulosus*. Amer. Natur. 35(419): 911–918.

Faber, D. J. 1970. Ecological observations on newly hatched lake whitefish in South Bay, Lake Huron, p. 481–500. *In* C. C. Lindsey and C. S. Woods [ed.] Biology of coregonid fishes. Univ. Manitoba Press, Winnipeg, Man. 560 p.

Fabricius, E., and K.-J. Gustafson. 1954. Further aquarium observations on the spawning behaviour of the char, *Salmo alpinus* L. Rep. Inst. Freshwater Res. Drottningholm 35: 58–104.

Fabricius, O. F. 1780. Fishes, p. 125–183. *In* Fauna Groenlandica. Copenhagen and Leipzig. 452 p.

Fahy, W. E. 1954. The life history of the northern greenside darter, *Etheostoma blennioides blennioides* Rafinesque. J. Elisha Mitchell Sci. Soc. 70: 139–205.

Fallis, B. W. MS 1970. The ecology of an exotic population of kokanee *Oncorhynchus nerka* (Walbaum) in Boulter Lake, Ontario. M.Sc. Thesis. Dep. Zool. Univ. Toronto, Toronto, Ont. 110 p.

Fedoruk, A. N. 1969. Checklist of and key to the freshwater fishes of Manitoba. Manitoba Dep. Mines Natur. Resources, Canada Land Inventory Project Rep. 6: 98 p.

Fenderson, O. C. 1964. Evidence of sub-populations of lake whitefish, *Coregonus clupeaformis*, involving a dwarfed form. Trans. Amer. Fish. Soc. 93(1): 77–94.

Ferguson, R. G. 1958. The preferred temperature of fish and their midsummer distribution in temperate lakes and streams. J. Fish. Res. Board Canada 15(4): 607–624.

—— 1965. Bathymetric distribution of American smelt *Osmerus mordax* in Lake Erie. Great Lakes Res. Div. Univ. Mich. Publ. 13: 47–60.

Fischthal, J. H. 1942. *Triganodistomum hypentelii* n.sp. (Trematoda: Lissorchidae) from the hog sucker, *Hypentelium nigricans* (LeSueur). J. Parasitol. 28(5): 389–393.

Fish, M. P. 1927. Contributions to the embryology of American eel. Zoologica 8: 289–324.

—— 1929. Contributions to the early life histories of Lake Erie fishes, p. 76–95. *In* Suppl. 18th Ann. Rep. N.Y. Conserv. Dep. 1928. 244 p.

—— 1932. Contributions to the early life histories of sixty-two species of fishes from Lake Erie and its tributary waters. Bull. U.S. Bur. Fish. 10, Vol. 47: 293–398.

Fisk, M. 1913. A review of the fishes of the genus *Osmerus* of the California coast. Proc. U.S. Nat. Mus. 46(2027): 29–297.

Flickinger, S. A. 1969. Determination of sexes in the fathead minnow. Trans. Amer. Fish. Soc. 98(3): 526–527.

Flittner, G. A. MS 1964. Morphometry and life history of the emerald shiner, *Notropis atherinoides* Rafinesque. Ph.D. Thesis. Univ. Michigan, Ann Arbor, Mich.

Foerster, R. E. 1925. Studies in the ecology of the sockeye salmon (*Oncorhynchus nerka*). Contrib. Can. Biol. n s. 2(16): 335–422.

—— 1935. Inter-specific cross-breeding of Pacific salmon. Trans. Roy. Soc. Canada ser. 3, 29, sec. 5: 21–33.

—— 1947. Experiment to develop sea-run from land-locked sockeye salmon (*Oncorhynchus nerka kennerlyi*). J. Fish. Res. Board Canada 7(2): 88–93.

—— 1955. The Pacific salmon (genus *Oncorhynchus*) of the Canadian Pacific coast, with particular reference to their occurrence in or near fresh water. Int. North Pac. Fish. Comm. Bull. 1: 1–56.

—— 1968. The sockeye salmon, *Oncorhynchus nerka*. Fish. Res. Board Canada Bull. 162: 422 p.

Foerster, R. E., and A. L. Pritchard. 1935. A study of the variation in certain meristic characters in the genus *Oncorhynchus* in British Columbia. Trans. Roy. Soc. Canada ser. 3, 29, sec. 5: 85–95.

Foerster, R. E., and W. E. Ricker. 1942. The effect of reduction of predaceous fish on survival of young sockeye salmon at Cultus Lake. J. Fish. Res. Board Canada 5(4): 315–336.

—— 1953. The coho salmon of Cultus Lake and Sweltzer Creek. J. Fish. Res. Board Canada 10(6): 293–319.

Forbes, S. A. 1878. *Episema jejuna* Forbes, n.s. Bull. Ill. State Lab. Natur. Hist. 1: 60–61.

—— 1885. Description of new Illinois fishes. Bull. Ill. State Lab. Natur. Hist. 2(2): 135–139.

Forbes, S. A., and R. E. Richardson. 1920. The fishes of Illinois. State Ill. Natur. Hist. Survey Div. 357 p.

Forelle, F. 1857. On the classification of fishes. With particular reference to the fishes of Canada. Can. Natur. Geol. 1, art. 43: 275–283.

Forney, J. L. 1955. Life history of the black bullhead, *Ameiurus melas* (Rafinesque), of Clear Lake, Iowa. Iowa State Coll. J. Sci. 30(1): 145–162.

—— 1957. Bait fish production in New York ponds. N.Y. Fish Game J. 4(2): 150–194.

Forney, J. L., and C. B. Taylor. 1963. Age and growth of white bass in Oneida Lake, New York. N.Y. Fish Game J. 10(2): 194–200.

Forster, J. R. 1771. Catalogue of the animals of North America containing an enumeration of the known quadrupeds, birds, reptiles, fish . . . London. 43 p.

—— 1773. An account of some curious fishes, sent from Hudson Bay. Phil. Trans. Roy. Soc. London 63(1): 149–160.

Fortin, Pierre. 1863. List of the cetacea, fishes, crustacea and mollusca, which now inhabit and have been inhabiting the Canadian shores of the Gulf of St. Lawrence and are objects of fishing operations, whether on a large or small scale, and which are used as bait, etc. *In* Annual report of Pierre Fortin, Esq., Magistrate in command of the expedition for the protection of the fisheries in the Gulf of St. Lawrence, during the seasons of 1861 and 1862. Appendix. p. 109–124.

—— 1864. Continuation of the list of fish of the Gulf and River St. Lawrence, p. 60–72. *In* Annual report of Pierre Fortin, Esq., commanding the expedition for the protection of the fisheries in the Gulf of St. Lawrence during the season of 1863. Fisheries appendices from Annual Report for 1863, of the Hon. Wm. McDougal, commissioner of crown lands for the year 1863.

—— 1865. Continuation of the list of fishes found in the Gulf and River St. Lawrence, p. 61–69. *In* Annual report of Pierre Fortin, Esq., stipendiary magistrate, commander of the expedition for the protection of fisheries in the Gulf of St. Lawrence on board *La Canadienne* during the season of 1864.

—— 1866. Continuation of the list of fishes taken in the Gulf and River St. Lawrence, p. 69–79. *In* Annual report of Pierre Fortin, Esq., stipendiary magistrate in command of the expedition for the protection of the fisheries in the Gulf of St. Lawrence, on board *La Canadienne* during the season of 1865.

Foster, F. J. 1918. White perch notes and methods of propagation. Trans. Amer. Fish. Soc. 48: 160–165.

Fowler, H. W. 1948. Fishes of the Nueltin Lake expedition, Keewatin. 1947. Part 1 — taxonomy. Proc. Acad. Natur. Sci. Philadelphia 100: 141–152.

—— 1961. Taxonomic notes on fishes of the interior of the Ungava Peninsula. J. Elisha Mitchell Sci. Soc. 77(2): 309–311.

Fowler, H. W., and F. Harper. 1948. Fishes of the Nueltin Lake Expedition, Keewatin, 1947. Part 1. Taxonomy. 25 text-figs. (Fowler). Part 2. Historical and field notes. Plates 10 and 11 (Harper). Proc. Acad. Natur. Sci. Philadelphia 100: 141–203 + pls. 12, 13, 14.

Fox, W. S. 1930. The literature of *Salmo salar* in Lake Ontario and tributary streams. Trans. Roy. Soc. Canada ser. 3, 24, sec. 2: 45–55.

Fraser, J. M. 1955. The smallmouth bass fishery of South Bay, Lake Huron. J. Fish. Res. Board Canada 12(1): 147–177.

Freeman, R. S., and B. H. Thompson. 1969. Observations on transmission of *Diphyllobothrium* sp. (Cestoda) to lake trout in Algonquin Park, Canada. J. Fish. Res. Board Canada 26(4): 871–878.

Freese, M. 1970. Distribution of *Triaenophorus crassus* parasites in whitefish flesh and its significance to automatic detection of the parasites with ultrasound. J. Fish. Res. Board Canada 27(2): 271–279.

Fry, F. E. J. 1937. The summer migration of the cisco, *Leucichthys artedi* (LeSueur), in Lake Nipissing, Ontario. Univ. Toronto Stud. Biol. Ser. 44, Publ. Ont. Fish. Res. Lab. 55: 91 p.

Fry, F. E. J., and K. E. F. Watt. 1957. Yields of year classes of the smallmouth bass hatched in the decade of 1940 in Manitoulin Island waters. Trans. Amer. Fish. Soc. 85 (1955): 135–143.

Fuchs, E. H. 1967. Life history of the emerald shiner, *Notropis atherinoides*, in Lewis and Clark Lake, South Dakota. Trans. Amer. Fish. Soc. 96(3): 247–256.

Fuller, W. A. 1955. The inconnu (*Stenodus leucichthys mackenziei*) in Great Slave Lake and adjoining waters. J. Fish. Res. Board Canada 12(5): 768–780.

Gaffney, J. J. 1960. Utilization of the mountain whitefish *Coregonus williamsoni* in Montana. Proc. Montana Acad. Sci. 19: 92–106. (Also, Contrib. Montana State Coll. Agric. Exper. Sta. Project MS-844, Pap. 335 J ser.)

Gage, J. F. 1963. The landlocked salmon or ouananiche in Ontario. Ont. Fish Wildlife Rev. 2(2): 2–7.

Gage, S. H. 1928. The lampreys of New York State — life history and economics, p. 158–191. *In* A biological survey of the Oswego River System. Suppl. 17th Ann. Rep. N.Y. Conserv. Dep. 1927. 371 p.

Garlick, T. 1857. A treatise on the artificial propagation of fish, with the description and habits of such kinds as are the most suitable for pisciculture; also, directions for the most successful modes of angling for such kind of fish as are herein described. T. Brown, New York and Cleveland. 142 p.

Garman, S. 1893. The lac de Marbre trout. A new species. Science, July 14. p. 23.

Garside, E. T. 1966. Developmental rate and vertebral number in salmonids. J. Fish. Res. Board Canada 23(10): 1537–1551.

Garside, E. T., and C. M. Jordan. 1968. Upper lethal temperatures at various levels of salinity in the euryhaline cyprinodontids *Fundulus heteroclitus* and *F. diaphanus* after isosmotic acclimation. J. Fish. Res. Board Canada 25(12): 2717–2720.

Garside, E. T., and J. S. Tait. 1958. Preferred temperature of rainbow trout (*Salmo gairdneri* Richardson) and its unusual relationship to acclimation temperature. Can. J. Zool. 36(3): 563–567.

Gasowska, M. 1960. Genus *Coregonus* L. discussed in connection with a new systematic feature, that of shape and proportion of os maxillare and os supramaxillare. Ann. Zool. Inst. Zool. Polska Akad. Nauk 18: 471–513.

Gee, J. H., and T. C. Northcote. 1963. Comparative ecology of two sympatric species of dace (*Rhinichthys*) in the Fraser River system, British Columbia. J. Fish. Res. Board Canada 20(1): 105–118.

Geen, G. H., T. G. Northcote, G. F. Hartman, and C. C. Lindsey. 1966. Life histories of two species of catostomid fishes in Sixteenmile Lake, British Columbia, with particular reference to inlet spawning. J. Fish. Res. Board Canada 23(11): 1761–1788.

Gerald, J. W. 1966. Food habits of the longnose dace, *Rhinichthys cataractae*. Copeia 1966(3): 478–485.

Gerking, S. D. 1945. The distribution of the fishes of Indiana. Invest. Indiana Lakes Streams 3(1): 1–137 + maps 1–113.

Gibbons, W. P. 1855. (Description of a new trout.) Proc. Calif. Acad. Natur. Sci. 1 (1854): 36.

Gibbs, R. H., Jr. 1957. Cyprinid fishes of the subgenus *Cyprinella* of *Notropis*. II. Distribution and variation of *Notropis spilopterus*, with the description of a new subspecies. Lloydia 20(3): 186–211.

Gilbert, C. H. 1895. The ichthyological collections of the steamer "*Albatross*" during the years 1890 and 1891. Rep. U.S. Fish Comm. (1893) 19: 392–476.

—— 1922. The salmon of the Yukon River. Bull. U.S. Bur. Fish. (1921–1922) 38, doc. 928: 317–332.

Gilbert, C. R. MS 1953. Age and growth of the yellow stone catfish, *Noturus flavus* (Rafinesque). M.Sc. Thesis. Ohio State Univ., Columbus, Ohio. 67 p.

—— 1964. The American cyprinid fishes of the subgenus *Luxilus* (genus *Notropis*). Bull. Florida State Mus. Biol. Sci. 8(2): 95–194.

Gilchrist, F. C. 1888. Assiniboia fisheries. Sess. Pap. Dom. Canada 21(8): 304–308.

Gill, T. N. 1859. Description of a new genus of Pimelodinae from Canada. Ann. Lyceum Natur. Hist. N.Y. 7. p. 40.

—— 1862. Catalogue of the fishes of the eastern coast of North America from Greenland to Georgia. Proc. Acad. Natur. Sci. Philadelphia 13 (suppl.): 1–63.

—— 1863. Note on some genera of fishes of western North America. Proc. Acad. Natur. Sci. Philadelphia (1862) 14: 329–332.

—— 1865. Synopsis of the fishes of the Gulf of St. Lawrence and Bay of Fundy. Can. Natur. 2: 244–266.

—— 1903. A remarkable genus of fishes — the umbras. Smithsonian Misc. Collect. 45: 295–305.

Gillespie, G. J. 1967. Gaspereaux fishing in the Maritimes. Fish. Canada 20(1): 14–16.

Girard, C. F. 1850. A monograph of the freshwater Cotti. Proc. Amer. Assoc. Adv. Sci. 2nd meet. (1849). p. 409–411.

—— 1852. Contributions to the natural history of the freshwater fishes of North America. I. A monograph of the cottoids. Smithsonian Contrib. Knowl. 3(art. 3): 80 p.

—— 1854a. *Salmo oquassa*. Proc. Boston Soc. Natur. Hist. 4: 262.

—— 1854b. Description of a supposed new species of *Salmo*. Proc. Acad. Natur. Sci. Philadelphia 6: 380–381.

—— 1856a. Descriptions of new fishes collected by A. L. Heermann, naturalist attached to the survey of the Pacific railroad, under Lieut. R. S. Williamson, U.S.A. Proc. Acad. Natur. Sci. Philadelphia (1854–55), 7: 129–136.

—— 1856b. Notice upon the viviparous fishes inhabiting the Pacific coast of North America, with an enumeration of the species observed. Proc. Acad. Natur. Sci. Philadelphia (1854–55), 7: 318–323.

—— 1857a. Researches upon the cyprinoid fishes inhabiting the fresh waters of the United States west of the Mississippi valley, from specimens in the museum of the Smithsonian Institution. Proc. Acad. Natur. Sci. Philadelphia (1856), 8: 165–213.

—— 1857b. Notice upon the species of the genus *Salmo* of authors, observed chiefly in Oregon and California. Proc. Acad. Natur. Sci. Philadelphia (1856) 8: 217–220.

—— 1859. Fishes. *In* General report on the zoology of the several Pacific railroad routes. U.S. Pac. R.R. Surv. 10(4): 400 p.

—— 1860. Ichthyological notices. Proc. Acad. Natur. Sci. Philadelphia (1859) 11: 56–68; 100–104; 113–122; 157–161.

Gmelin, J. F. 1788. Caroli a Linné, systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. Vol. 1 (Regnum animale). 13th ed., aucta, reformata. Lipsiae. Georg. Emmanuel. Beer.

Godfrey, H. 1955. On the ecology of Skeena River whitefishes, *Coregonus* and *Prosopium*. J. Fish. Res. Board Canada 12(4): 499–541.

—— 1957. Feeding of eels in four New Brunswick salmon streams. Fish. Res. Board Canada Progr. Rep. Atl. 67: 19–22.

—— 1965. Salmon of the North Pacific Ocean — Part 9. 1. Coho salmon in offshore waters. Int. North Pac. Fish. Comm. Bull. 15: 39 p.

Godfrey, J., Jr. 1945. Muskies unlimited. Outdoors, October.

Goode, G. B. 1903. American fishes. Dana Estes & Co. Boston, Mass. 562 p.

Gosline, W. A. 1947. Some meristic characters in a population of the fish *Poecilichthys exilis*: their variation and correlation. Occas. Pap. Mus. Zool. Univ. Mich. 500: 23 p. + 2 pls.

—— 1966. The limits of the fish family Serranidae, with notes on other lower percoids. Proc. Calif. Acad. Sci. 4th Ser. 33(6): 91–112 + 10 figs., 1 table.

Goss, R. J., and M. W. Stagg. 1957. The regeneration of fins and fin rays in *Fundulus heteroclitus*. J. Exp. Zool. 136(3): 487–503.

Gould, W. R. III, and W. H. Irwin. 1965. The suitabilities and relative resistances of twelve species of fish as bioassay animals for oil-refinery effluents. Proc. S. E. Assoc. Game Fish Comm. 16: 333–348.

Gowanloch, J. N. 1927. Notes on the occurrence and control of the trematode, *Gyrodactylus*, ectoparasitic on *Fundulus*. Proc. Trans. Nova Scotian Inst. Sci. 16(3): 126–131.

Graham, J. J. 1956. Observations on the alewife, *Pomolobus pseudoharengus* (Wilson), in fresh water. Univ. Toronto Stud. Biol. Ser. 62, Publ. Ont. Fish. Res. Lab. 74: 43 p.

—— 1957. Some observations on the schooling movements of the alewife in Lake Ontario. Can. Field-Natur. 71(3): 115–116.

Grainger, E. H. 1953. On the age, growth, migration, reproductive potential and feeding habits of the Arctic char (*Salvelinus alpinus*) of Frobisher Bay, Baffin Island. J. Fish. Res. Board Canada 10(6): 326–370.

Gray, J. W. MS 1942. Studies of *Notropis atherinoides atherinoides* Rafinesque, in the Bass Islands region of Lake Erie. M.Sc. Thesis. Ohio State Univ., Columbus, Ohio. 29 p.

Greeley, J. R. 1927. Fishes of the Genesee Region with annotated list, p. 47–66. *In* A biological survey of the Genesee River system. Suppl. 16th Ann. Rep. N.Y. Conserv. Dep. 1926. 100 p.

—— 1929. Fishes of the Erie–Niagara watershed, p. 150–179. *In* A biological survey of Erie–Niagara system. Suppl. 18th Ann. Rep. N.Y. Conserv. Dep. 1928. 244 p.

—— 1930. Fishes of the Lake Champlain watershed, p. 44–87. *In* A biological survey of the Champlain watershed. Suppl. 19th Ann. Rep. N.Y. Conserv. Dep. 1929. 321 p.

—— 1932. The spawning habits of the brook, brown, and rainbow trout and the problem of egg predators. Trans. Amer. Fish. Soc. 62 (1932): 239–248.

—— 1934. Fishes of the Raquette watershed with annotated list, p. 53–108. *In* A biological survey of the Raquette watershed. Suppl. 23rd Ann. Rep. N.Y. Conserv. Dep. 1933. 301 p.

—— 1936. Fishes of the area with annotated list, p. 45–88. *In* A biological survey of the Delaware and Susquehanna watersheds. Suppl. 25th Ann. Rep. N.Y. Conserv. Dep. 1935. 356 p.

—— 1937. Fishes of the area with an annotated list, p. 45–103. *In* A biological survey of the lower Hudson watershed. Suppl. 26th Ann. Rep. N.Y. Conserv. Dep. 1936. 373 p.

—— 1938. Fishes of the area with annotated list, p. 48–73. *In* A biological survey of the Allegheny and Chemung watersheds. Suppl. 27th Ann. Rep. N.Y. Conserv. Dep. 1937. 287 p.

—— 1939. The freshwater fishes of Long Island and Staten Island with annotated list, p. 29–44. *In* A biological survey of the freshwaters of Long Island. Suppl. 28th Ann. Rep. N.Y. Conserv. Dep. 1938. 128 p.

—— 1940. Fishes of the watershed with annotated list, p. 42–81. *In* A biological survey of the Lake Ontario watershed. Suppl. 29th Ann. Rep. N.Y. Conserv. Dep. 1939. 261 p.

Greeley, J. R., and C. W. Greene. 1931. Fishes of the area with annotated list, p. 44–94. *In* A biological survey of the St. Lawrence watershed. Suppl. 20th Ann. Rep. N.Y. Conserv. Dep. 1930. 261 p.

Green, A. 1891. The economic fishes of British Columbia. Proc. Natur. Hist. Soc. Brit. Columbia 1: 20–33.

Greenbank, J. 1957. Aggregational behavior in a freshwater sculpin. Copeia 1957(2): 157.

Greenbank, J., and P. R. Nelson. 1958. Life history of the threespine stickleback *Gasterosteus aculeatus* Linnaeus in Karluk Lake and Bare Lake, Kodiak Island, Alaska. U.S. Fish Wildlife Serv. Fish. Bull. 153, Vol. 59: 537–559.

Greene, C. W. 1935. The distribution of Wisconsin fishes. State Wis. Conserv. Comm. Madison, Wis. 235 p.

Greene, G. N. 1962. White bass feeding: scent or sight. Trans. Amer. Fish. Soc. 91(3): 326.

Greenwood, P. H., D. E. Rosen, S. H. Weitzman, and G. S. Myers. 1966. Phyletic studies of teleostean fishes, with a provisional classification of living forms. Bull. Amer. Mus. Natur. Hist. 131(4): 341–355.

Gruchy, C. G., and W. B. Scott. 1966. *Lepomis megalotis*, the longear sunfish, in western Ontario. J. Fish. Res. Board Canada 23(9): 1457–1459.

Gruchy, C. G., and V. D. Vladykov. 1968. Sexual dimorphism in anal fin of brown trout, *Salmo trutta*, and close relatives. J. Fish. Res. Board Canada 25(4): 813–815.

Gudger, E. W. 1937. A glut herring, *Pomolobus aestivalis*, with an attached colonial hydroid, *Obelia commensuralis*. Amer. Mus. Novitates 945: 6 p. + 3 text-figs.

Guilford, H. G. 1963. New species of Myxosporidia found in percid fishes from Green Bay (Lake Michigan). J. Parasitol. 49(3): 474–478.

Güldenstadt, A. J. 1772. *Salmo leucichthys* et *Cyprinus chalcoides*. Novi Comment. Acad. Petropol. 16 (1771): 531–547.

Günther, A. 1860–1870. Catalogue of fishes of the British Museum. Vol. 2 (1860): 548 p.; vol. 3 (1861): 586 p.; vol. 4 (1862): 534 p.; vol. 5 (1864): 455 p.; vol. 6 (1866): 368 p.; vol. 7 (1868): 512 p.; vol. 8 (1870): 549 p. London.

—— 1877a. An account of the fishes collected by Capt. Fielden between 78° and 83° N. lat. during the Arctic Expedition of 1875–6. Proc. Zool. Soc. London. p. 293–295.

—— 1877b. Report on a collection of fishes made by Mr. C. Hart during the late Arctic expedition. Proc. Zool. Soc. London. p. 475–477.

—— 1895. (2nd edition). Catalogue of fishes of the British Museum. 1: 391 p. + 15 pls. London.

Hagen, D. W. 1967. Isolating mechanisms in threespine sticklebacks (*Gasterosteus*). J. Fish. Res. Board Canada 24(8): 1637–1692.

Hagen, D. W., and J. D. McPhail. 1970. The species problem within *Gasterosteus aculeatus* on the Pacific coast of North America. J. Fish. Res. Board Canada 27(1): 147–155.

Hagen, H. K. 1970. Age, growth and reproduction of the mountain whitefish in Phelps Lake, Wyoming. p. 399–415. *In* C. C. Lindsey and C. S. Woods [ed.] Biology of coregonid fishes. Univ. Manitoba Press, Winnipeg, Man. 560 p.

Haley, A. J. 1952. Preliminary observation on a severe epidemic of microsporidiosis in the smelt, *Osmerus mordax* (Mitchill). J. Parasitol. 38: 183.

Halkett, A. 1913. Check list of the fishes of the Dominion of Canada and Newfoundland. King's Printer. Ottawa. 138 p.

Hall, J. D. MS 1960. Preliminary studies on the biology of native Michigan lampreys. M.Sc. Thesis. Univ. Michigan, Ann Arbor, Mich. 39 p.

—— MS 1963. An ecological study of the chestnut lamprey, *Ichthyomyzon castaneus* Girard in the Manistee River, Michigan. Ph.D. Thesis. Univ. Mich. Diss. Abstract 24(2): 901–902.

Hallam, J. C. 1959. Habitat and associated fauna of four species of fish in Ontario streams. J. Fish. Res. Board Canada 16(2): 147–173.

Hamada, Keikichi. 1961. Taxonomic and ecological studies of the genus *Hypomesus* of Japan. Mem. Fac. Fish. Hokkaido Univ. 9(1): 1–55 + 9 pls.

Hanek, G., and W. Threlfall. 1970. Helminth parasites of the fourspine stickleback (*Apeltes quadracus* (Mitchill)) in Newfoundland. Can. J. Zool. 48(2): 404–406.

Hankinson, T. L. 1930. Breeding behavior of the silverfin minnow, *Notropis whipplii spilopterus* (Cope). Copeia 1930(3): 73–74.

Hansen, D. F. 1951. Biology of the white crappie in Illinois. Bull. Ill. Natur. Hist. Surv. 25(4): 211–265.

—— 1965. Further observations on nesting of the white crappie, *Pomoxis annularis*. Trans. Amer. Fish. Soc. 94(2): 182–184.

Harkness, W. J. K. 1922. The rate of growth of the yellow perch (*Perca flavescens*) in Lake Erie. Univ. Toronto Stud. Biol. Ser. 20, Publ. Ont. Fish. Res. Lab. 6: 87–95.

—— 1923. The rate of growth and the food of the lake sturgeon (*Acipenser rubicundus* LeSueur). Univ. Toronto Stud. Biol. Ser. 24, Publ. Ont. Fish. Res. Lab. 18: 15–42.

Harkness, W. J. K., and J. R. Dymond. 1961. The lake sturgeon. The history of its fishery and problems of conservation. Ont. Dep. Lands Forests, Fish Wildlife Br. 121 p.

Harkness, W. J. K., and J. L. Hart. 1927. The fishes of Long Lake, Ontario. Univ. Toronto Stud. Biol. Ser. 29, Publ. Ont. Fish. Res. Lab. 29: 21–31.

Harkness, W. J. K., and W. E. Ricker. 1929. A preliminary study of some trout waters of Ontario. Trans. Amer. Fish. Soc. 59: 256–267.

Harlan, J. R., and E. B. Speaker. 1969. Iowa fish and fishing. State Conserv. Comm., Des Moines, Iowa. 365 p.

Harper, F. 1948. Fishes of the Nueltin Lake expedition, Keewatin, 1947. Part 2 — Historical and field notes. Proc. Acad. Natur. Sci. Philadelphia 50: 153–184.

—— 1961. Field and historical notes on fresh-water fishes of the Ungava Peninsula and on certain marine fishes of the north shore of the Gulf of St. Lawrence. J. Elisha Mitchell Sci. Soc. 77(2): 312–342.

Harper, F., and J. T. Nichols. 1919. Six new fishes from northwestern Canada. Bull. Amer. Mus. Natur. Hist. 41(2): 263–270.

Harrington, R. W., Jr. 1947a. The breeding behavior of the bridled shiner, *Notropis bifrenatus*. Copeia 1947(3): 186–192.

—— 1947b. Observations on the breeding habits of the yellow perch *Perca flavescens* (Mitchill). Copeia 1947(3): 199–200.

—— 1948a. The life cycle and fertility of the bridled shiner, *Notropis bifrenatus* (Cope). Amer. Midland Natur. 39(1): 83–92.

—— 1948b. The food of the bridled shiner, *Notropis bifrenatus* (Cope). Amer. Midland Natur. 40(2): 353–361.

—— 1955. The osteocranium of the American cyprinid fish, *Notropis bifrenatus*, with an annotated synonymy of teleost skull bones. Copeia 1955(4): 267–290.

Harris, R. H. D. 1962. Growth and reproduction of the longnose sucker, *Catostomus catostomus* (Forster), in Great Slave Lake. J. Fish. Res. Board Canada 19(1): 113–126.

Hart, J. L. 1928. Data on the rate of growth of pike perch (*Stizostedion vitreum*) and sauger (*S. canadense*) in Ontario. Univ. Toronto Stud. Biol. Ser. 31, Publ. Ont. Fish. Res. Lab. 34: 43–55.

—— 1930. The spawning and early life history of the whitefish, *Coregonus clupeaformis* (Mitchill), in the Bay of Quinte, Ontario. Contrib. Can. Biol. Fish. 6(7): 165–214.

—— 1931. The growth of the whitefish *Coregonus clupeaformis* (Mitchill). Contrib. Can. Biol. Fish. 6(20): 427–444.

—— 1973. Pacific fishes of Canada. Fish. Res. Board Canada Bull. 180: 740 p.

Hart, J. L., and R. G. Ferguson. 1966. The American smelt. Trade News 18(9): 22–23.

Hart, J. L., and J. L. McHugh. 1944. The smelts (Osmeridae) of British Columbia. Fish. Res. Board Canada Bull. 64: 27 p.

Hart, J. S. 1952. Geographic variations of some physiological and morphological characters in certain freshwater fish. Univ. Toronto Biol. Ser. 60, Publ. Ont. Fish. Res. Lab. 72: 79 p.

Hartman, G. F. MS 1956. A taxonomic study of cutthroat trout, *Salmo clarki clarki* Richardson, rainbow trout, *Salmo gairdneri* Richardson, and reciprocal hybrids. M.A. Thesis. Univ. British Columbia, Vancouver, B.C.

—— 1965. The role of behavior in the ecology and interaction of underyearling coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri*). J. Fish. Res. Board Canada 22(4): 1035–1081.

Hartman, G. F., and C. A. Gill. 1968. Distributions of juvenile steelhead and cutthroat trout (*Salmo gairdneri* and *S. clarki clarki*) within streams in southwestern British Columbia. J. Fish. Res. Board Canada 14(5): 687–691.

Hartman, G. F., T. G. Northcote, and C. C. Lindsey. 1962. Comparison of inlet and outlet spawning runs of rainbow trout in Loon Lake, British Columbia. J. Fish. Res. Board Canada 19(2): 173–200.

Hauser, W. J. 1969. Life history of the mountain sucker, *Catostomus platyrhynchus*, in Montana. Trans. Amer. Fish. Soc. 98(2): 209–215.

Havey, K. A., and K. Warner. 1970. The landlocked salmon (*Salmo salar*). Its life history and management in Maine. Sport Fish. Inst. Washington, and Maine Dep. Inland Fish. Game. 129 p.

Hay, O. P. 1881. On a collection of fishes from eastern Mississippi. Proc. U.S. Nat. Mus. (1880) 3: 488–515.

Hazzard, A. S., and M. J. Madsen. 1933. Studies of the food of the cutthroat trout. Trans. Amer. Fish. Soc. 63 (1933): 198–203.

Heard, W. R. 1965. Limnetic cottid larvae and their utilization as food by juvenile sockeye salmon. Trans. Amer. Fish. Soc. 94(2): 191–193.

—— 1966. Observations on lampreys in the Naknek River system of southwest Alaska. Copeia 1966(2): 332–339.

Heard, W. R., and W. L. Hartman. 1966. Pygmy whitefish *Prosopium coulteri* in the Naknek River system of southwest Alaska. U.S. Fish Wildlife Serv. Fish. Bull. 65(3): 555–579.

Heckel, J. J. 1840. Ichthyologische Beitrage zu den Familien der Cottoiden, Scorpaenoiden, Gobioiden, und Cyprinoiden. Ann. Wien. Mus. Natur. 2: 143–164.

Heckel, J. J., and L. J. Fitzinger. 1836. Monographische Darstellung der Gattung *Acipenser*. Ann. Wien. Mus. Natur. 1: 261–326.

Heiser, D. W. 1966. Age and growth of anadromous Dolly Varden char in Eva Creek, Baranof Island, southeastern Alaska. Alaska Dep. Fish Game Res. Rep. 5: 29 p.

Henderson, N. E., and R. E. Peter. 1969. Distribution of fishes of southern Alberta. J. Fish. Res. Board Canada 26(2): 325–338.

Henn, A. W. 1932. Part II. Zoology. Sec. 3. Some fishes of Southampton Island, p. 1–3. *In* The exploration of Southampton Island, Hudson Bay. Mem. Carnegie Mus. 12(2).

Henn, A. W., and W. H. Rinkenbach. 1925. Description of the aurora trout (*Salvelinus timagamiensis*), a new species from Ontario. Ann. Carnegie Mus. 16: 131–141.

Henry, K. A. 1961. Racial identification of Fraser River sockeye salmon by means of scales and its applications to salmon management. Int. Pac. Salmon Fish. Comm. Bull. 12: 97 p.

Herbert, H. W. 1850. Great northern pickerel. Frank Forester's fish and fishing of the United States and the British provinces of North America. 2nd ed., London. p. 1–359.

Hergenrader, G. L., and A. D. Hasler. 1968. Influence of changing seasons on schooling behavior of yellow perch. J. Fish. Res. Board Canada 25(4): 711–716.

Herman, E., W. Wisby, L. Wiegert, and M. Burdick. 1959. The yellow perch. Its life history, ecology, and management. Wis. Conserv. Dep. Publ. 228: 14 p.

Hermann, Johannes. 1804. Observations zoologicae, quibus novae complures, aliaeque animalium species describuntur et illustrantur. IV. Pisces: 290–328. (Opus posthumum edidit Fridericus Ludovicus Hammer.) Argentoratium and Paris. Amandus Koenig: p. i–viii, 1–332.

Herting, G. E., and W. Witt, Jr. 1968. Rate of digestion in the bowfin. Progr. Fish-Cult. 30(1): 26–28.

Hervey, G. F., and J. Hems. 1968. The goldfish. Faber and Faber, London. 271 p.

Hester, F. E. 1970. Phylogenetic relationships of sunfishes as demonstrated by hybridization. Trans. Amer. Fish. Soc. 99(1): 100–104.

Hildebrand, S. F. 1963. Family Clupeidae, p. 257–454. *In* Fishes of the western North Atlantic. Mem. Sears Found. Mar. Res. 1(3): 630 p.

Hildebrand, S. F., and W. C. Schroeder. 1928. Fishes of Chesapeake Bay. U.S. Bur. Fish. Bull. 43(1), doc. 1024: 366 p.

Hile, R. 1937. Morphometry of the cisco, *Leucichthys artedi* (Le Sueur), in the lakes of the northeastern highlands, Wisconsin. Sonderdruck aus; Int. Rev. d. ges. Hydr. u. Hydr. Leipzig 36(1/2): 57–130.

Hile, R., and H. J. Buettner. 1955. Commercial fishery for chubs (ciscoes) in Lake Michigan through 1953. U.S. Fish Wildlife Serv. Spec. Sci. Rep. Fish. 163: 49 p.

Hinks, David. 1943. The fishes of Manitoba. Man. Dep. Mines Natur. Res. 102 p.

Hoar, W. S. 1951. The chum and pink salmon fisheries of British Columbia, 1917–1947. Fish. Res. Board Canada Bull. 90: 46 p.

—— 1952. Thyroid function in some anadromous and landlocked teleosts. Trans. Roy. Soc. Can. 46: 39–53.

Hodder, V. M. 1966. Two further records of the American shad in Newfoundland waters. Trans. Amer. Fish. Soc. 95(2): 228–229.

Hoffman, G. L. 1960. Synopsis of Strigeoidea (Trematoda) of fishes and their life cycles. U.S. Fish Wildlife Serv. Fish. Bull. 175, Vol. 60: 439–469.

—— 1967. Parasites of North American freshwater fishes. Univ. California Press, Los Angeles, Calif. 486 p.

Hofstetter, A. M., C. F. Dineen, and P. S. Stokely. 1958. Skeletal differences between the black and white crappies. Trans. Amer. Microsc. Soc. 77: 19–21.

Hogman, W. J. 1968. Annulus formation on scales of four species of coregonids reared under artificial conditions. J. Fish. Res. Board Canada 25(10): 2111–2122.

—— 1970. Early scale development on the Great Lakes coregonids, *Coregonus artedii* and *C. kiyi*, p. 429–436. *In* C. C. Lindsey and C. S. Woods [ed.] Biology of coregonid fishes. Univ. Manitoba Press, Winnipeg, Man. 560 p.

Hollis, E. H. 1952. Variations in the feeding habits of the striped bass, *Roccus saxatilis* (Walbaum), in Chesapeake Bay. Bull. Bingham Oceanogr. Collect. 14(1): 111–131.

Holloway, A. D. 1954. Notes on the life history and management of the shortnose and longnose gars in Florida waters. J. Wildlife Manage. 18(4): 438–449.

Holt, R. D. 1960. Comparative morphometry of the mountain whitefish, *Prosopium williamsoni*. Copeia 1960(3): 192–200.

Hooper, F. F. 1949. Age analysis of a population of the ameiurid fish *Schilbeodes mollis* (Hermann). Copeia 1949(1): 34–38.

Hoover, E. E. 1936. Contributions to the life history of the chinook and landlocked salmon in New Hampshire. Copeia 1936(4): 193–198.

Houde, E. D. 1964. The strigeid trematode, *Crassiphiala bulboglossa*, from the blacknose dace, *Rhinichthys atratulus*. Trans. Amer. Fish. Soc. 93(3): 304–306.

Hourston, A. S. 1952. The food and growth of the maskinonge (*Esox masquinongy* Mitchill) in Canadian waters. J. Fish. Res. Board Canada 8(5): 347–368.

—— 1955. A study of variations in the maskinonge from three regions in Canada. Roy. Ont. Mus. Zool. Palaeont. Contrib. 40: 13 p. + 16 fig.

Hoy, P. R. 1872. Deep-water fauna of Lake Michigan. Trans. Wis. Acad. Sci. Arts Lett. 1870–1872: 98–101.

—— 1873. Deep-water fauna of Lake Michigan. Ann. Mag. Natur. Hist. 11 (4th ser.): 319–320.

Hubbs, C. L. 1921a. An ecological study of the life-history of the fresh-water atherine fish *Labidesthes sicculus*. Ecology 2(4): 262–276.

—— 1921b. Geographical variation of *Notemigonus crysoleucas* — an American minnow. Trans. Ill. State Acad. Sci. 11: 147–151.

—— 1925a. The life-cycle and growth of lampreys. Pap. Mich. Acad. Sci. Arts Lett. (1924) 4(1): 587–603.

—— 1925b. A revision of the osmerid fishes of the North Pacific. Proc. Biol. Soc. Washington 38: 49–56.

—— 1926. A check-list of the fishes of the Great Lakes and tributary waters, with nomenclatorial notes and analytical keys. Univ. Mich. Mus. Zool. Misc. Publ. 15: 77 p.

—— 1927. The related effects of a parasite on a fish. J. Parasitol. 14(2): 75–84.

—— 1929. The Atlantic American species of the fish genus *Gasterosteus*. Occas. Pap. Mus. Zool. Univ. Mich. 200: 9 p. + 2 pls.

—— 1930a. Materials for a revision of the catostomid fishes of eastern North America. Univ. Mich. Mus. Zool. Misc. Publ. 20: 47 p.

—— 1930b. Further additions and corrections to the list of the fishes of the Great Lakes and tributary waters. Pap. Mich. Acad. Sci. Arts Lett. 11 (1929): 425–436.

—— 1931. Studies of the fishes of the order Cyprinodontes. X. Four nominal species of *Fundulus* placed in synonymy. Occas. Pap. Mus. Zool. Univ. Mich. 231: 8 p.

—— 1936. An older name for the black-nosed dace. Copeia 1936(2): 124–125.

—— 1942. Sexual dimorphism in the cyprinid fishes, *Margariscus* and *Couesius*, and alleged hybridization between these genera. Occas. Pap. Mus. Zool. Univ. Mich. 468: 6 p.

—— 1947. *Tirodon*, a neglected nominal genus of American cyprinid fishes. Copeia 1947(3): 175–176.

Hubbs, C. L., and R. M. Bailey. 1938. The small-mouthed bass. Cranbrook Inst. Sci. Bull. 10: 92 p.

Hubbs, C. L., and D. E. S. Brown. 1929. Materials for a distributional study of Ontario fishes. Trans. Roy. Can. Inst. 17(1): 56 p.

Hubbs, C. L., and G. P. Cooper. 1935. Age and growth of the long-eared and the green sunfishes in Michigan. Pap. Mich. Acad. Sci. Arts Lett. 20: 669–696 + 5 pls.

—— 1936. Minnows of Michigan. Cranbrook Inst. Sci. Bull. 8: 95 p.

Hubbs, C. L., and W. R. Crowe. 1956. Preliminary analysis of the American cyprinid fishes, seven new, referred to the genus *Hybopsis*, subgenus *Erimystax*. Occas. Pap. Mus. Zool. Univ. Mich. 578: 8 p.

Hubbs, C. L., and G. W. Greene. 1928. Further notes on the fishes of the Great Lakes and tributary waters. Pap. Mich. Acad. Sci. Arts Lett. (1927) 8: 371–392.

Hubbs, C. L., and K. F. Lagler. 1939. Keys for the identification of the fishes of the Great Lakes and tributary waters. Ann Arbor, Mich. 37 p. (Mimeo.)

—— 1941. Guide to the fishes of the Great Lakes and tributary waters. Cranbrook Inst. Sci. Bull. 18: 100 p.

—— 1947. Fishes of the Great Lakes region. Cranbrook Inst. Sci. Bull. 26: (xi) + 186 p., 251 figs., 26 col. pls., 38 text-figs.

—— 1949. Fishes of Isle Royale, Lake Superior, Michigan. Pap. Mich. Acad. Sci. Arts Lett. (1947) 33: 73–133 + 2 pls.

—— 1958. Fishes of the Great Lakes region. Univ. Mich. Press, Ann Arbor, Mich. 213 p.

—— 1964. Fishes of the Great Lakes region. Univ. Mich. Press, Ann Arbor, Mich. xv + 213 p.

Hubbs, C. L., and R. R. Miller. 1948. The Great Basin. II. The zoological evidence. Bull. Univ. Utah 38(20): 17–144.

Hubbs, C. L., and T. E. B. Pope. 1937. The spread of the sea lamprey through the Great Lakes. Trans. Amer. Fish. Soc. 66 (1936): 172–176.

Hubbs, C. L., and E. C. Raney. 1944. Systematic notes on North American siluroid fishes of the genus *Schilbeodes*. Occas. Pap. Mus. Zool. Univ. Mich. 487: 36 p. + 1 pl., 1 map.

Hubbs, C. L., and L. P. Schultz. 1931. The scientific name of the Columbia River chub. Occas. Pap. Mus. Zool. Univ. Mich. 232: 6 p. + 1 pl.

—— 1932. A new catostomid fish from the Columbia River. Univ. Washington Publ. Biol. 2(1): 1–14.

—— 1941. Contributions to the ichthyology of Alaska, with descriptions of two new fishes. Occas. Pap. Mus. Zool. Univ. Mich. 431: 31 p.

Hubbs, C. L., and M. B. Trautman. 1937. A revision of the lamprey genus *Ichthyomyzon*. Univ. Mich. Mus. Zool. Misc. Publ. 35: 109 p.

Hubbs, C. L., B. W. Walker, and R. E. Johnson. 1943. Hybridization in nature between species of American cyprinodont fishes. Contrib. Lab. Vertebrate Biol. Univ. Mich. 23: 21 p. + 6 pls.

Hubbs, Clark. 1961. Developmental temperature tolerances of four etheostomatine fishes occurring in Texas. Copeia 1961(2): 195–198.

Huck, L. L., and G. E. Gunning. 1967. Behavior of the longear sunfish, *Lepomis megalotis* (Rafinesque). Tulane Stud. Zool. 14(3): 121–131.

Hume, L. C. 1955. Rainbow trout spawn twice a year. Calif. Fish Game 41(1): 117.

Hunter, G. W. III. 1930. Contributions to the life cycle of *Centrovarium lobotes* (MacCallum 1895). J. Parasitol. 17(2): 108.

Hunter, G. W. III, and J. S. Rankin, Jr. 1939. Parasites of northern pike and pickerel. Trans. Amer. Fish. Soc. 69 (1939): 268–272.

Hunter, J. G. 1959. Survival and production of pink and chum salmon in a coastal stream. J. Fish. Res. Board Canada 16(6): 835–886.

—— 1966. The Arctic char. Fish. Canada 19(3): 17–19.

—— 1970. Production of arctic char (*Salvelinus alpinus* Linnaeus) in a small arctic lake. Fish. Res. Board Canada Tech. Rep. 231: 190 p.

Hunter, J. R. 1963. The reproductive behavior of the green sunfish, *Lepomis cyanellus*. Zoologica 48(1): 13–24.

Hunter, J. R., and A. D. Hasler. 1965. Spawning association of the redfin shiner, *Notropis umbratilis*, and the green sunfish, *Lepomis cyanellus*. Copeia 1965(3): 265–281.

Hunter, J. R., and W. J. Wisby. 1961. Utilization of the nests of green sunfish (*Lepomis cyanellus*) by the redfin shiner (*Notropis umbratilis cyanocephalus*). Copeia 1961(1): 113–115.

Huntsman, A. G. 1917. The lampreys of eastern Canada. Ottawa Natur. 31(2): 23–27.

—— 1922. The fishes of the Bay of Fundy. Contrib. Can. Biol. (1921), 3: 49–72.

—— 1931. The maritime salmon of Canada. Biol. Board Canada Bull. 21: 99 p.

—— 1944. Why did Ontario salmon disappear? Trans. Roy. Soc. Canada ser. 3, 38, sec. 5: 83–102.

Huntsman, G. R. 1967. Nuptial tubercles in carpsuckers (*Carpiodes*). Copeia 1967(2): 457–458.

Hussokof, L. 1913. Sea lampreys and their nests. Amer. Mus. J. 13: 323–325.

Hynes, H. B. N. 1950. The food of fresh-water sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungitius*), with a review of methods used in studies of the food of fishes. J. Anim. Ecol. 19: 36–58.

Idyll, C. 1942. Food of rainbow, cutthroat, and brown trout in the Cowichan River system, B.C. J. Fish. Res. Board Canada 5(5): 448–458.

Ievleva, M. Ya. 1951. Morphology and rate of embryonic development of Pacific salmon. Izv. Tikhookean. Nauch-Issled. Inst. Ryb. Khoz. Okeanogr. 34: 123–130.

Innes, W. T. 1947. Goldfish varieties and water gardens. Innes Publications, Philadelphia, Pa. 381 p.

Jackson, V. W. 1934. A manual of vertebrates of Manitoba. Univ. Manitoba, Winnipeg, Man. 42 p. + figs.

Jacobs, D. L. 1948. Nesting of the brook stickleback. (Abstract.) Proc. Minnesota Acad. Sci. 16: 33–34.

Jacoby, C. MS 1953. Notes on the life history of the deepwater sculpin, *Myoxocephalus quadricornis* L., in Lake Superior. M.Sc. Thesis. Univ. Michigan School Natur. Res., Ann Arbor, Mich. 21 p.

—— 1961. Relative growth of fins in the fourhorn sculpin, *Myoxocephalus quadricornis*, from the upper Great Lakes. Copeia 1961(4): 473–475.

Jean, Yves. 1946. Two northern longnose gars, *Lepisosteus osseus oxyurus* Rafinesque, caught in the estuary of the St. Lawrence, Quebec. Copeia 1946(2): 100.

Jeffers, G. W. 1932. Fishes observed in the Strait of Belle Isle. Contrib. Can. Biol. Fish., n.s. 7(16): 203–211.

Jenkins, J. T. 1958. The fishes of the British Isles, both fresh water and salt. Frederick Warne and Co. Ltd., London. 408 p.

Jenkins, R. E. MS 1970. Systematic studies of the catostomid fish tribe Moxostomatini. Ph.D. Thesis. Cornell Univ., Ithaca, N.Y. 800 p.

Jensen, Ad. S. 1937. Remarks on the Greenland eel, its occurrence and reference to *Anguilla rostrata*. Medd. om. Grønland 118(9): 1–8.

Jeppson, P. W. 1957. The control of squawfish by use of dynamite, spot treatment, and reduction of lake levels. Progr. Fish-Cult. 19(4): 168–171.

JEPPSON, P. W., and W. S. PLATTS. 1959. Ecology and control of the Columbia squawfish in northern Idaho lakes. Trans. Amer. Fish. Soc. 88(3): 197–202.

JOB, S. V. 1955. The oxygen consumption of *Salvelinus fontinalis*. Univ. Toronto Stud. Biol. Ser. 61, Publ. Ont. Fish. Res. Lab. 73: 39 p.

JOBES, F. W. 1943. The age, growth, and bathymetric distribution of Reighard's chub, *Leucichthys reighardi* Koelz, in Lake Michigan. Trans. Amer. Fish. Soc. 72 (1942): 108–135.

—— 1949a. The age, growth, and distribution of the longjaw cisco, *Leucichthys alpenae* Koelz, in Lake Michigan. Trans. Amer. Fish. Soc. 76 (1946): 215–247.

—— 1949b. The age, growth, and bathymetric distribution of the bloater, *Leucichthys hoyi* (Gill) in Lake Michigan. Pap. Mich. Acad. Sci. Arts Lett. 33 (1947): 135–172.

—— 1952. Age, growth, and production of yellow perch in Lake Erie. U.S. Fish Wildlife Serv. Fish Bull. 70, Vol. 52: 205–266.

JOERIS, L. S. 1957. Structure and growth of scales of yellow perch of Green Bay. Trans. Amer. Fish. Soc. 86 (1956): 169–194.

JOHANNES, R. E., and P. A. LARKIN. 1961. Competition for food between redside shiners (*Richardsonius balteatus*) and rainbow trout (*Salmo gairdneri*) in two British Columbia lakes. J. Fish. Res. Board Canada 18(2): 203–220.

JOHN, K. R. 1956. Onset of spawning activities of the shallow water cisco, *Leucichthys artedi* (LeSueur), in Lake Mendota, Wisconsin, relative to water temperatures. Copeia 1956(2): 116–118.

JOHN, K. R., and A. D. HASLER. 1956. Observations on some factors affecting the hatching of eggs and the survival of young shallowwater cisco, *Leucichthys artedi* LeSueur, in Lake Mendota, Wisconsin. Limnol. Oceanogr. 1(3): 176–194.

JOHNSON, D. W. 1968. Pesticides and fishes — a review of selected literature. Trans. Amer. Fish. Soc. 97(4): 398–424.

JOHNSON, G. H. 1951. An investigation of the mooneye (*Hiodon tergisus*). Abstract 5th Tech. Sess. Res. Council, Ontario. p. 16.

JOHNSON, L. 1964. Marine-glacial relicts of the Canadian arctic islands. Syst. Zool. 13(2): 76–91.

JOHNSON, L., G. H. LAWLER, and L. A. SUNDE. MS 1970. Rainbow trout farming in central Canada. Fish. Res. Board Canada Tech. Rep. 165: 9 p. + appendix, 6 figs.

JOHNSON, M. G. 1965. Estimates of fish populations in warmwater streams by the removal method. Trans. Amer. Fish. Soc. 94(4): 350–357.

JOHNSON, M. G., and H. R. MCCRIMMON. 1967. Survival, growth, and reproduction of largemouth bass in southern Ontario ponds. Progr. Fish-Cult. 29(4): 216–221.

JOHNSON, R. P. 1963. Studies on the life history and ecology of the bigmouth buffalo, *Ictiobus cyprinellus* (Valenciennes). J. Fish. Res. Board Canada 20(6): 1397–1429.

JONES, J. M. 1882. List of the fishes of Nova Scotia. Proc. Nova Scotian Inst. Natur. Sci. V. pt. Appendix 1: 87–97.

JONES, J. W. 1959. The salmon. Collins, London. 192 p.

JONES, J. W., and H. B. N. HYNES. 1950. The age and growth of *Gasterosteus aculeatus*, *Pygosteus pungitius* and *Spinachia vulgaris*, as shown by their otoliths. J. Anim. Ecol. 19: 59–73.

JORDAN, D. S. 1876. Manual of the vertebrates of the northern United States, including the district east of the Mississippi river and north of North Carolina and Tennessee, exclusive of marine species. A. C. McLurg, Chicago. 342 p.

—— 1877a. ii. A. Notes on Cottidae, Etheostomatidae, Percidae, Centrarchidae, Aphododeridae, Dorysomatidae and Cyprinidae, with revisions of the genera and descriptions of new or little known species. B. Synopsis of the Siluridae of the fresh waters of North America. *In* Contributions to North American ichthyology; based primarily on the collections of the United States National Museum. Bull. U.S. Nat. Mus. 1877–78, 10: 1–116.

—— 1877b. A partial synopsis of the fishes of upper Georgia with supplementary papers on fishes of Tennessee, Kentucky, and Indiana. Ann. N.Y. Lyceum Natur. Hist. 11: 307–377.

—— 1878a. On the distribution of freshwater fishes of the United States. Ann. N.Y. Acad. Sci. 1(4): 92–120.

—— 1878b. iii. B. A synopsis of the family Catostomidae. *In* Contributions to North American ichthyology; based primarily on the collections of the United States National Museum. Bull. U.S. Nat. Mus. 12: 97–230.

—— 1878c. Manual of the vertebrates of the northern United States, including the district east of the Mississippi river and north of North Carolina and Tennessee, exclusive of marine species. 2nd ed. Chicago. 407 p.

—— 1886. Note on the scientific name of the yellow perch, the striped bass, and other North American fishes. Proc. U.S. Nat. Mus. (1885) 8: 72–73.

—— 1888. A manual of the vertebrate animals of the northern United States, including the district north and east of the Ozark mountains, south of the Laurentian hills, north of the southern boundary of Virginia, and east of the Missouri river; inclusive of marine species. 5th ed. A. C. McLurg, Chicago. 375 p.

—— 1892. Description of a new species of salmon. Forest Stream 39: 405–406.

—— 1893. Description of a new species of cyprinoid fish, *Couesius greeni*, from the head waters of Frazer River in British Columbia. Proc. U.S. Nat. Mus. 16(938): 313–314.

—— 1924. Concerning the American dace allied to the genus *Leuciscus*. Copeia 1924(132): 70–72.

—— 1926. The name of the brook trout of Europe. Copeia 1926(155): 140–141.

Jordan, D. S., and H. E. Copeland. 1876. Check list of the fishes of the fresh waters of North America, p. 133–164. *In* Vol. 3. Bull. Buffalo Soc. Natur. Sci. (1875–1877). 230 p.

—— 1878. A catalogue of the fishes of the fresh waters of North America. U.S. Geol. Geogr. Surv. Terr. (Hayden) Bull. 4: 407–442.

Jordan, D. S., and B. W. Evermann. 1896–1900. The fishes of North and Middle America. Bull. U.S. Nat. Mus. 47(1–4): 3313 p. + 392 pls.

—— 1908. American food and game fish. Doubleday, Page & Co., Garden City, N.Y. 572 p.

—— 1909. Descriptions of three new species of cisco, or lake herring (*Argyrosomus*), from the Great Lakes of America; with a note on the species of whitefish. Proc. U.S. Nat. Mus. 36(1662): 165–172.

—— 1911. A review of the salmonoid fishes of the Great Lakes, with notes on the whitefishes of other regions. Bull. Bur. Fish. 29 (1909), doc. 737: 1–41 + 7 pls.

Jordan, D. S., B. W. Evermann, and H. W. Clark. 1930. Check list of the fishes and fishlike vertebrates of North and Middle America. Reprint Appendix X to Rep. U.S. Comm. Fish. (1928). 670 p.

Jordan, D. S., and M. W. Fordice. 1886. Review of the North American species of Petromyzontidae. Ann. N.Y. Acad. Sci. (1885) 3: 279–296.

Jordan, D. S., and C. H. Gilbert. 1883a. A synopsis of the fishes of North America. Bull. U.S. Nat. Mus. 16: 1–1018.

—— 1883b. Description of a new species of *Uranidea* (*Uranidea pollicaris*) from Lake Michigan. Proc. U.S. Nat. Mus. (1882) 5: 222–223.

Jordan, D. S., and W. F. Thompson. 1910a. Description of a new species of deep-water sculpin (*Triglopsis ontariensis*) from Lake Ontario, with notes on related species. Proc. U.S. Nat. Mus. 38(1728): 75–78.

—— 1910b. Note on the gold-eye, *Amphiodon alosoides* Rafinesque, or *Elattonistius chrysopsis* (Richardson). Proc. U.S. Nat. Mus. 38(1752): 353–357 + 2 fig.

Karr, J. R. 1963. Age, growth, and food habits of johnny, slenderhead and blacksided darters of Boone County, Iowa. Proc. Iowa Acad. Sci. 70: 228–236.

—— 1964. Age, growth, fecundity and food habits of fantail darters in Boone County, Iowa. Proc. Iowa Acad. Sci. 71: 274–280.

Kasahara, H. 1963. Salmon of the north Pacific ocean — Part 1. Catch statistics for north Pacific salmon. Int. North Pac. Fish. Comm. Bull. 12: 7–82.

Katz, M. 1954. Reproduction of fish. Data for Handb. Biol. Data. 22 p.

Katz, M., J. C. Woodey, C. D. Becker, P. T. K. Woo, and J. R. Adams. 1966. Records of *Cryptobia salmositica* from sockeye salmon from the Fraser River drainage and from the state of Washington. J. Fish. Res. Board Canada 23(12): 1965–1966.

Kaup, J. J. 1856. Uebersicht der Aale. Arch. Naturgesch. 22(1): 41–77.

Keast, A. 1965. Resource subdivision amongst cohabiting fish species in a bay, Lake Opinicon, Ontario. Publ. Great Lakes Res. Div. Univ. Mich. 13: 106–132.

—— 1968a. Feeding biology of the black crappie, *Pomoxis nigromaculatus*. J. Fish. Res. Board Canada 25(2): 285–297.

—— 1968b. Feeding of some Great Lakes fishes at low temperatures. J. Fish. Res. Board Canada 25(6): 1199–1218.

Keast, A., and D. Webb. 1966. Mouth and body form relative to feeding ecology in the fish fauna of a small lake, Lake Opinicon, Ontario. J. Fish. Res. Board Canada 23(12): 1845–1867.

Keast, A., and L. Welsh. 1968. Daily feeding periodicities, food uptake rates, and dietary changes with hour of day in some lake fishes. J. Fish. Res. Board Canada 25(6): 1133–1144.

Keenleyside, M. H. A. 1955. Some aspects of the schooling behaviour of fish. Behaviour 8(2, 3): 183–248.

Keleher, J. J. MS 1950. Growth, maturity, and *Triaenophorus* parasitism in relation to taxonomy of Lake Winnipeg ciscoes (*Leucichthys*). Fish. Res. Board Canada MS Rep. Biol. Sta. 509: 69 p.

—— 1952a. Notes on fishes collected from Lake Winnipeg region. Can. Field-Natur. 66(6): 170–173.

—— 1952b. Growth and *Triaenophorus* parasitism in relation to taxonomy of Lake Winnipeg ciscoes (*Leucichthys*). J. Fish. Res. Board Canada 8(7): 469–478.

—— MS 1953. Growth of ciscoes, *Leucichthys* sp., collected from five different lakes. Fish. Res. Board Canada MS Rep. Biol. Sta. 557: 9 p. + 12 tables.

—— 1956. The northern limits of distribution in Manitoba for cyprinid fishes. Can. J. Zool. 34(4): 263–266.

—— 1961. Comparison of largest Great Slave Lake fish with North American records. J. Fish. Res. Board Canada 18(3): 417–421.

—— 1966. A survey of Great Slave Lake fishing. North 13(1): 50–53.

Keleher, J. J., and B. **Kooyman**. 1957. Supplement to Hinks' "The fishes of Manitoba". Dep. Mines Natur. Res. Prov. Manitoba. p. 104–117.

Kelley, J. W. 1962. Sexual maturity and fecundity of the largemouth bass, *Micropterus salmoides* (Lacépède), in Maine. Trans. Amer. Fish. Soc. 91(1): 23–28.

Kelly, H. A. 1924. *Amia calva* guarding its young. Copeia (1924)133: 73–74.

Kendall, W. C. 1895. Notes on the freshwater fishes of Washington county, Maine. Bull. U.S. Fish. Comm. (1894) 14: 43–54.

—— 1896. Description of a new stickleback, *Gasterosteus gladiunculus*, from the coast of Maine. Proc. U.S. Nat. Mus. 18(1089): 623–624.

—— 1909. The fishes of Labrador. Proc. Portland Soc. Natur. Hist. 2: 207–248.

—— 1910. American catfishes: habits, culture, and commercial importance. U.S. Bur. Fish. Doc. 733: 39 p. + 10 pls.

—— 1911. Notes on *Percopsis guttatus* Agassiz and *Salmo omiscomaycus* Walbaum. Proc. Biol. Soc. Washington 24: 45–52.

—— 1917. The pikes: their geographical distribution, habits, culture, and commercial importance. Rep. U.S. Fish. Comm. (1917), Bur. Fish. Doc. 853: 1–45.

—— 1919. Concerning the generic name, *Cristivomer* vs. *Salvelinus*, for the Great Lakes trout or namaycush. Copeia 1919(74): 78–81.

—— 1927. The smelts. Bull. U.S. Bur. Fish. 42, doc. 1015: 217–375.

—— 1935. The fishes of New England. The salmon family. Part 2 — The salmons. Mem. Boston Soc. Natur. Hist. 9(1): 166 p. + 11 pls.

Kennamer, E. F. (undated). Catfish for fun and cash. Auburn Univ. Coop. Exten. Serv. Circ. E-15, Auburn, Ala. 35 p.

Kennedy, W. A. 1943. The whitefish, *Coregonus clupeaformis* (Mitchill), of Lake Opeongo, Algonquin Park, Ontario. Univ. Toronto Stud. Biol. Ser. 51, Publ. Ont. Fish. Res. Lab. 62: 21–66.

—— 1949a. Relationship of length, weight and sexual maturity to age in three species of Lake Manitoba fish. Fish. Res. Board Canada Bull. 81: 5 p.

—— 1949b. Some observations on the coregonine fish of Great Bear Lake, N.W.T. Fish. Res. Board Canada Bull. 82: 10 p.

—— 1953a. The morphometry of the coregonine fishes of Great Bear Lake, N.W.T. J. Fish. Res. Board Canada 10(2): 51–61.

—— 1953b. Growth, maturity, fecundity and mortality in the relatively unexploited whitefish, *Coregonus clupeaformis*, of Great Slave Lake. J. Fish. Res. Board Canada 10(7): 413–441.

—— 1954a. Tagging returns, age studies and fluctuations in abundance of Lake Winnipeg whitefish 1931–1951. J. Fish. Res. Board Canada 11(3): 284–309.

—— 1954b. Growth, maturity and mortality in the relatively unexploited lake trout, *Cristivomer namaycush*, of Great Slave Lake. J. Fish. Res. Board Canada 11(6): 827–852.

—— 1963. Growth and mortality of whitefish in three unexploited lakes in northern Canada. J. Fish. Res. Board Canada 20(2): 265–272.

Kennedy, W. A., and W. M. **Sprules**. 1967. Goldeye in Canada. Fish. Res. Board Canada Bull. 161: 45 p.

Kerswill, C. J. MS 1937. A taxonomic and distributional study of *Amphiodon alosoides* and *Hiodon tergisus*. M.A. Thesis. Univ. Western Ontario, London, Ont. 67 p. + 10 pls.

Khan, N. Y., and S. U. **Qadri**. 1970. Morphological differences in Lake Superior lake char. J. Fish. Res. Board Canada 27(1): 161–167.

Kinney, E. C., **Jr.** MS 1950. The life-history of the trout perch, *Percopsis omiscomaycus* (Walbaum), in western Lake Erie. M.Sc. Thesis. Ohio State Univ., Columbus, Ohio. 75 p.

—— MS 1954. A life history study of the silver chub, *Hybopsis storeriana* (Kirtland), in western Lake Erie with notes on associated species. Ph.D. Thesis. Ohio State Univ., Columbus, Ohio. 99 p.

Kirtland, J. P. 1838. Report on the zoology of Ohio. 2nd Ann. Rep. Geol. Surv. State Ohio (by W. W. Mather, principal geologist and the several assistants). p. 157–200.

—— 1841a. Descriptions of four new species of fishes. Boston J. Natur. Hist. 3(3): 273–279.

—— 1841b. Descriptions of the fishes of the Ohio River and its tributaries. Boston J. Natur. Hist. vol. 3: 338–352; 469–482. vol. 4: 16–26; 303–308. vol. 5: 21–32.

—— 1844a. Descriptions of *Acipenser rubicundus*, *A. platyrhynchus* and *Rutilus Storerianus*. Proc. Boston Soc. Natur. Hist. (1841–1844) 1: 71.

—— 1844b. Description of *Leuciscus Storerianus*, sp. nov., from Ohio. Proc. Boston Soc. Natur. Hist. (1841–1844) 1: 199–200.

—— 1850. Fishes of Ohio. Fragments of natural history. The family visitor. Cleveland (and Hudson) 1(1): 1–2.

—— 1854a. *Alburnus nitidus* (Silvery minnow). *In* The Annals of Science, being a record of inventions and improvements in applied science: including the transactions of the Cleveland Acad. Natur. Sci. 2 (February): 44.

—— 1854b. Revision of the species belonging to the genus *Esox*, inhabiting Lake Erie and the River Ohio. *In* The Annals of Science, being a record of inventions and improvements in applied science: including the transactions of the Cleveland Acad. Natur. Sci. 2(3): 78–79.

Kitchell, J. F., and J. T. Windell. 1970. Nutritional value of algae to bluegill sunfish, *Lepomis macrochirus*. Copeia 1970(1): 186–190.

Klawe, W. L. 1957. Common mummichog and newt in a lake on Digby Neck, Nova Scotia. Can. Field-Natur. 71(3): 154–155.

Kleerekoper, H. 1969. Olfaction in fishes. Indiana Univ. Press, Bloomington, Ind. 222 p.

Kleinert, S. J., and D. Mraz. 1966. Life history of the grass pickerel (*Esox americanus vermiculatus*) in southeastern Wisconsin. Wis. Conserv. Dep. Tech. Bull. 37: 40 p.

Kliewer, E. V. 1970. Gillraker variation and diet in lake whitefish *Coregonus clupeaformis* in northern Manitoba, p. 147–165. *In* C. C. Lindsey and C. S. Woods [ed.], Biology of coregonid fishes. Univ. Manitoba Press, Winnipeg, Man. 560 p.

Klocke, J. F., P. I. Tack, M. A. Ohlson, R. Nitchals, E. Leffler, and N. S. Henry. 1947. Nutritive value of fish from Michigan waters. II. Thiamin of lake herring, carp, common sucker, burbot and smelt. Food Res. 12(1): 37–43.

Kluikanov, V. A. 1969. Morphological bases of classification of smelts of the genus *Osmerus* (Osmeridae). Zool. J. 48(1). (Can. Dep. Sec. State Translation 2196)

Knapp, L. W. MS 1964. Systematic studies of the rainbow darter, *Etheostoma caeruleum* (Storer), and the subgenus *Hadropterus* (Pisces, Percidae). Ph.D. Thesis. Cornell Univ. Ithaca, N.Y. 206 p.

Knight, A. E. 1963. The embryonic and larval development of the rainbow trout. Trans. Amer. Fish. Soc. 92(4): 344–355.

Knight, T. F. 1866. Fishes of Nova Scotia. Descriptive catalogue of fishes of Nova Scotia. Halifax, N.S. 54 p.

Koelz, W. 1921. Description of a new cisco from the Great Lakes. Occas. Pap. Mus. Zool. Univ. Mich. 104: 4 p.

—— 1924. Two new species of cisco from the Great Lakes. Occas. Pap. Mus. Zool. Univ. Mich. 146: 8 p.

—— 1925. Description of a new cisco from the Great Lakes basin. Occas. Pap. Mus. Zool. Univ. Mich. 158: 3 p.

—— 1929. Coregonid fishes of the Great Lakes. Bull. U.S. Bur. Fish. 43, 1927, 2, doc. 1048: 297–643.

—— 1931. The coregonid fishes of northeastern America. Pap. Mich. Acad. Sci. Arts Lett. 13 (1930): 303–432.

Kolbe, C. F. 1944. Food. The controlling factor of fish populations and other related factors influencing survival of valuable species. Port Dover, Ont. 29 p.

Kooyman, A. H. MS 1970. Taxonomy of the whitefishes in Waskesiu Lake, Saskatchewan. M.Sc. Thesis. Dep. Biol., Univ. Calgary, Calgary, Alta. 88 p.

Koshinsky, G. D. 1965. Limnology and fisheries of five precambrian headwater lakes near Lac la Ronge, Saskatchewan. Fish. Branch, Dep. Natur. Res., Sask. Fish. Rep. 7: 52 p.

Koster, W. J. MS 1936. The life-history and ecology of the sculpins (Cottidae) of central New York. Ph.D. Thesis. Cornell Univ., Ithaca, N.Y. 2 p. (unnumbered).

—— 1937. The food of sculpins (Cottidae) in central New York. Trans. Amer. Fish. Soc. 66 (1936): 374–382.

—— 1939. Some phases of the life history and relationships of the cyprinid, *Clinostomus elongatus* (Kirtland). Copeia 1939(4): 201–208.

Kramer, R. H., and L. L. Smith, Jr. 1960a. Utilization of nests of largemouth bass, *Micropterus salmoides*, by golden shiners, *Notemigonus crysoleucas*. Copeia 1960(1): 73–74.

—— 1960b. First-year growth of the largemouth bass, *Micropterus salmoides* (Lacépède), and some related ecological factors. Trans. Amer. Fish. Soc. 89(2): 222–233.

—— 1962. Formation of year classes in largemouth bass. Trans. Amer. Fish. Soc. 91(1): 29–41.

Krejsa, R. J. 1967a. The systematics of the prickly sculpin, *Cottus asper* Richardson, a polytypic species. Part I. Synonymy, nomenclatural history, and distribution. Pac. Sci. 21(2): 241–251.

—— 1967b. The systematics of the prickly sculpin, *Cottus asper* Richardson, a polytypic species. Part II. Studies on the life history, with especial reference to migration. Pac. Sci. 21(3): 414–422.

Krueger, W. H. 1961. Meristic variation in the fourspine stickleback, *Apeltes quadracus*. Copeia 1961(4): 442–450.

Krumholz, L. A., and H. S. Cavanah. 1968. Comparative morphometry of freshwater drum from two midwestern localities. Trans. Amer. Fish. Soc. 97(4): 429–441.

Kuehn, J. H. 1957. Life history and ecology of the long-nose dace. Data for Handb. Biol. Data. 2 p.

Kuntz, A., and L. Radcliffe. 1917. Notes on the embryology and larval development of twelve teleostean fishes. Bull. U.S. Bur. Fish. 35, 1915–16, doc. 849: 89–134.

Kutkuhn, J. H. 1958. Utilization of gizzard shad by game fishes. Proc. Iowa Acad. Sci. 65: 571–579.

La Cepède, B. G. 1802. Histoire naturelle des poissons. Vol. 4. Plassan, Paris. 728 p.

—— 1803. Histoire naturelle des poissons. Vol. 5. Plassan, Paris. 803 p.

Lachner, E. A. 1952. Studies of the biology of the cyprinid fishes of the chub genus *Nocomis* of northeastern United States. Amer. Midland Natur. 48(2): 433–466.

Lachner, E. A., and R. E. Jenkins. 1967. Systematics, distribution, and evolution of the chub genus *Nocomis* (Cyprinidae) in the southwestern Ohio River Basin, with the description of a new species. Copeia 1967(3): 557–580.

Lagler, K. F. 1956. The pike, *Esox lucius* Linnaeus, in relation to waterfowl on the Seney National Wildlife Refuge, Michigan. J. Wildlife Manage. 20(2): 114–124.

Lagler, K. F., and F. V. Hubbs. 1940. Food of the long-nosed gar (*Lepisosteus osseus oxyurus*) and the bowfin (*Amia calva*) in southern Michigan. Copeia 1940(4): 239–241.

Lagler, K. F., D. B. Obrecht, and G. V. Harry. 1942. The food and habits of gars (*Lepisosteus* Spp.) considered in relation to fish management. Invest. Indiana Lakes Streams, Indiana Dep. Conserv. 2: 118–135.

Lagler, K. F., and A. T. Wright. 1962. Predation of the Dolly Varden, *Salvelinus malma*, on young salmons, *Oncorhynchus* spp., in an estuary. Trans. Amer. Fish. Soc. 88(1): 90–93.

Lake, C. T. 1936. The life history of the fan-tailed darter, *Catonotus flabellaris flabellaris* (Rafinesque). Amer. Midland Natur. 17(5): 816–830.

LaLanne, J. J., and G. Safsten. 1969. Age determination from scales of chum salmon (*Oncorhynchus keta*). J. Fish. Res. Board Canada 26(3): 671–681.

Lamsa, A. 1963. Downstream movements of brook sticklebacks, *Eucalia inconstans* (Kirtland), in a small southern Ontario stream. J. Fish. Res. Board Canada 20(2): 587–589.

Langford, R. R. 1938. The food of the Lake Nipissing cisco, *Leucichthys artedi* (LeSueur), with special reference to the utilization of the limnetic crustacea. Univ. Toronto Stud. Biol. Ser. 45, Publ. Ont. Fish. Res. Lab. 57: 143–190.

Langlois, T. H. 1929. Breeding habits of the northern dace. Ecology 10(1): 161–163.

—— 1935. Notes on the spawning habits of the Atlantic smelt. Copeia 1935(3): 141–142.

—— 1936. Length-weight relationships of bullheads. Copeia 1936(2): 120.

—— 1954. The western end of Lake Erie and its ecology. Edwards Bros. Inc., Ann Arbor, Mich. 479 p.

Lantz, A. W. 1948. Experiments on the canning of freshwater fish. Fish. Res. Board Canada Progr. Rep. Pac. 74: 19–21.

—— 1962. Specialty fish products. Circ. (Gen. Ser.) Biol. Sta. London, Ont. 4: 10–28.

Lapworth, E. D. 1956. The effect of fry plantings on whitefish production in eastern Lake Ontario. J. Fish. Res. Board Canada 13(4): 547–558.

La Rivers, I. 1952. A key to Nevada fishes. Southern Calif. Acad. Sci. Bull. 51(3): 86–102.

—— 1962. Fishes and fisheries of Nevada. Nevada State Fish Game Comm. State Printing Office, Carson City, Nev. 782 p.

Larkin, P. A. MS 1945. Unpublished report in the files of the Department of Biology, Univ. Saskatchewan, Saskatoon, Sask.

Larkin, P. A., G. C. Anderson, W. A. Clemens, and D. C. G. Mackay. 1950. The production of Kamloops trout (*Salmo gairdnerii kamloops*, Jordan) in Paul Lake, British Columbia. Univ. British Columbia and Brit. Columbia Game Dep. 37 p.

Larkin, P. A., and S. B. Smith. 1954. Some effects of introduction of the redside shiner on the Kamloops trout in Paul Lake, British Columbia. Trans. Amer. Fish. Soc. 83 (1953): 161–175.

Larkin, P. A., J. G. Terpenning, and R. R. Parker. 1957. Size as a determinant of growth rate in rainbow trout *Salmo gairdneri*. Trans. Amer. Fish. Soc. 86 (1956): 84–96.

Larsen, A. 1954. First record of the white perch (*Morone americana*) in Lake Erie. Copeia 1954(2): 154.

Lawler, G. H. 1952. A new North American host for the fish parasite *Triaenophorus nodulosus* (Pallas). Can. Field-Natur. 66(4): 111.

—— MS 1953. Age, growth, production and infection with *Triaenophorus nodulosus* of the yellow perch, *Perca flavescens* (Mitchill) of Manitoba. Fish. Res. Board Canada MS Rep. Biol. Sta. 521: 19 p.

—— 1954. Observations on the trout-perch *Percopsis omiscomaycus* (Walbaum), at Heming Lake, Manitoba. J. Fish. Res. Board Canada 11(1): 1–4.

—— 1960. A mutant pike, *Esox lucius*. J. Fish. Res. Board Canada 17(5): 647–654.

—— 1961. Egg counts of Lake Erie whitefish. J. Fish. Res. Board Canada 18(2): 293–294.

—— 1963. The biology and taxonomy of the burbot, *Lota lota*, in Heming Lake, Manitoba. J. Fish. Res. Board Canada 20(2): 417–433.

—— 1964. Incidence of *Ligula intestinalis* in Heming Lake fish. J. Fish. Res. Board Canada 21(3): 549–554.

—— 1965a. Fluctuations in the success of year-classes of whitefish populations with special reference to Lake Erie. J. Fish. Res. Board Canada 22(5): 1197–1227.

—— 1965b. The food of the pike, *Esox lucius*, in Heming Lake, Manitoba. J. Fish. Res. Board Canada 22(6): 1357–1377.

—— 1969. Aspects of the biology of *Triaenophorus nodulosus* in yellow perch, *Perca flavescens*, in Heming Lake, Manitoba. J. Fish. Res. Board Canada 26(4): 821–831.

—— 1970. Parasites of coregonid fishes, p. 279–309. *In* C. C. Lindsey and C. S. Woods [ed.] Biology of coregonid fishes. Univ. Manitoba Press, Winnipeg, Man. 560 p.

Lawler, G. H., and M. Fitz-Earle. 1968. Marking small fish with stains for estimating populations in Heming Lake, Manitoba. J. Fish. Res. Board Canada 25(2): 255–266.

Lawler, G. H., and W. B. Scott. 1954. Notes on the geographical distribution and the hosts of the cestode genus *Triaenophorus* in North America. J. Fish. Res. Board Canada 11(6): 884–893.

Lawler, G. H., and N. H. F. Watson. 1958. Limnological studies of Heming Lake, Manitoba, and two adjacent lakes. J. Fish. Res. Board Canada 15(2): 203–217.

Leach, J. F. MS 1962. Summer food and feeding of the white perch *Roccus americanus* (Gmelin) in the Bay of Quinte. M.A. Thesis. Univ. Toronto, Toronto, Ont. 58 p.

Leach, W. J. 1940. Occurrence and life history of the northern brook lamprey, *Ichthyomyzon fossor*, in Indiana. Copeia 1940(1): 21–34.

LeCompte, E. L. 1926. The striped bass (rock fish) of the Atlantic coast. Trans. Amer. Fish. Soc. 56: 203–206.

Legendre, P. MS 1969. Two natural hybrids of the cyprinid fish *Chrosomus eos*. M.Sc. Thesis. Dep. Zool., McGill Univ., Montreal, Que. 119 p.

Legendre, V. 1942. Redécouverte après un siècle et reclassification d'une espèce de catostomidé. Natur. Can. 69(10 et 11): 227–233.

—— 1943. Un nouveau poisson pour la province de Québec. Rev. can. de Biol. 2(1): 105–107.

—— 1952. Clef des poissons de pêche sportive et commerciale de la Province de Québec. Soc. Can. d'Ecol. Montréal. xiii + 84 p.

—— 1953. The freshwater fishes of the Province of Quebec: list of the species, ecological groups, history, nomenclature, annotations. 9th Rep. Biol. Bur. Game Fish. Dep. Quebec, 1951–52. p. 190–294.

—— 1954. Key to game and commercial fishes of the Province of Quebec. Vol. 1. The freshwater fishes. Soc. Can. d'Ecol. Montreal. 180 p.

Legendre, V., and R. Lagueux. 1948. The tomcod (*Microgadus tomcod*) as a permanent fresh-water resident of Lake St. John, Province of Quebec. Can. Field-Natur. 65(5): 157.

Legendre, V., et J. Rousseau. 1949. La distribution de quelques-uns de nos poissons dans le Québec arctique. Annales de l'Acfas 15: 133–135.

Leggett, W. C., and G. Power. 1969. Differences between two populations of landlocked Atlantic salmon (*Salmo salar*) in Newfoundland. J. Fish. Res. Board Canada 26(6): 1585–1596.

Leim, A. H. 1924. The life history of the shad (*Alosa sapidissima* (Wilson)), with special reference to the factors limiting its abundance. Contrib. Can. Biol. n.s. 2(1): 163–284.

Leim, A. H., and W. B. Scott. 1966. Fishes of the Atlantic coast of Canada. Fish. Res. Board Canada Bull. 155: 485 p.

Le Jeune, R., and V. Legendre. 1968. Extension d'aire du saumon d'eau douce (*Salmo salar*) au Québec. Natur. Can. 95: 1169–1173.

Lennon, R. E. 1954. Feeding mechanism of the sea lamprey and its effect on host fishes. U.S. Fish Wildlife Serv. Fish. Bull. 98, Vol. 56: 247–293.

Leonard, A. K. 1927. The rate of growth and the food of the horned dace (*Semotilus atromaculatus*) in Quebec, with some data on the food of the common shiner (*Notropis cornutus*) and of the brook trout (*Salvelinus fontinalis*) from the same region. Univ. Toronto Stud. Biol. Ser. 28, Publ. Ont. Fish. Res. Lab. 30: 35–44.

LeSueur, C. A. 1817a. A short description of five (supposed) new species of the genus *Muraena*, discovered by Mr. Le Sueur, in the year 1816. J. Acad. Natur. Sci. Philadelphia 1(1): 81–83.

—— 1817b. Description of two new species of the genus *Gadus*. J. Acad. Natur. Sci. Philadelphia 1(1): 83–85.

—— 1817c. Description of a new species of the genus *Cyprinus*. J. Acad. Natur. Sci. Philadelphia 1(1): 85–86.

—— 1817d. A new genus of fishes of the order Abdominales, proposed under the name of *Catostomus*, and the characters of this genus, with those of its species, indicated. J. Acad. Natur. Sci. Philadelphia 1(1): 88–96; 102–111.

—— 1817e. Descriptions of four new species, and two varieties, of the genus *Hydrargira*. J. Acad. Natur. Sci. Philadelphia 1(1): 126–134.

—— 1818a. Descriptions of several new species of North American fishes. J. Acad. Natur. Sci. Philadelphia 1(2): 222–235; 359–368.

—— 1818b. Description of several new species of the genus *Esox*, of North America. J. Acad. Natur. Sci. Philadelphia 1(2): 413–417.

—— 1818c. Description of several species of chondropterygious fishes of North America, with their varieties. Trans. Amer. Phil. Soc., n.s. 1: 383–394.

—— 1819. Notice sur quelques poissons découverts dans les lacs du haut Canada, durant l'été de 1816. Mém. Mus. Hist. Natur. Paris, 5: 148–161.

—— 1822a. Descriptions of five new species of the genus *Cichla* of Cuvier. J. Acad. Natur. Sci. Philadelphia n.s. 2: 214–221.

—— 1822b. Description of three new species of the genus *Sciaena*. J. Acad. Natur. Sci. Philadelphia n.s. 2: 251–256.

—— 1827. American ichthyology, or natural history of the fishes of North America. New Harmony, Indiana. 44 p.

Levanidov, V. Ya., and I. M. Levanidova. 1957. Food of downstream migrant young summer chum salmon and pink salmon in Amur tributaries. Izv. Tikhookean. Nauch-Issled. Inst. Ryb. Kohz. Okeanogr. 45: 3–16.

Lewis, C. MS 1965. The largemouth bass fishery, Lake Opinicon, Ontario. M.Sc. Thesis. Fac. Arts Sci. Queen's Univ. Kingston, Ont. 69 p.

Lewis, R. M. 1957. Comparative study of populations of the striped bass. U.S. Fish Wildlife Serv. Spec. Sci. Rep. Fish. 204: 54 p.

Lewis, W. M. 1949. The use of vertebrae as indicators of the age of the northern black bullhead *Ameiurus m. melas* (Rafinesque). Iowa State Coll. J. Sci. 23(2): 209–218.

Lewis, W. M., and G. E. Gunning. 1959. Notes on the life history of the steelcolor shiner, *Notropis whipplei* (Girard). Trans. Ill. State Acad. Sci. 52(1 and 2): 59–64.

Lindeborg, R. G. 1941. Records of fishes from the Quetico Provincial Park of Ontario, with comments on the growth of the yellow pike-perch. Copeia 1941(3): 159–161.

Lindsey, C. C. 1953. Variation in anal fin ray count of the redside shiner *Richardsonius balteatus* (Richardson). Can. J. Zool. 31(3): 211–225.

—— 1956. Distribution and taxonomy of fishes in the Mackenzie drainage of British Columbia. J. Fish. Res. Board Canada 13(6): 759–886.

—— 1958. Modification of meristic characters by light duration in kokanee, *Oncorhynchus nerka*. Copeia 1958(2): 134–136.

—— 1962. Distinctions between the broad whitefish, *Coregonus nasus*, and other North American whitefishes. J. Fish. Res. Board Canada 19(4): 687–714.

—— 1963. Status of the whitefish species *Coregonus nelsonii* Bean, with designation of a new type. Copeia 1963(1): 173–174.

—— 1964. Problems in zoogeography of the lake trout, *Salvelinus namaycush*. J. Fish. Res. Board Canada 21(5): 977–994.

Lindsey, C. C., J. W. Clayton, and W. G. Franzin. 1970. Zoogeographic problems and protein variation in the *Coregonus clupeaformis* whitefish species complex, p. 127–146. *In* C. C. Lindsey and C. S. Woods [ed.] Biology of coregonid fishes. Univ. Manitoba Press, Winnipeg, Man. 560 p.

Lindsey, C. C., and T. G. Northcote. 1963. Life history of redside shiners, *Richardsonius balteatus*, with particular reference to movements in and out of Sixteenmile Lake streams. J. Fish. Res. Board Canada 20(4): 1001–1030.

Lindsey, C. C., T. G. Northcote, and G. F. Hartman. 1959. Homing of rainbow trout to inlet and outlet spawning streams at Loon Lake, British Columbia. J. Fish. Res. Board Canada 16(5): 695–719.

Lindsey, C. C., and C. S. Woods [ed.] 1970. Biology of coregonid fishes. Univ. Manitoba Press, Winnipeg, Man. 560 p.

Linnaeus, C. 1758. Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. Laurentii Salvii, Holmiae, 10th ed., Vol. 1: 824 p.

—— 1766. Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. Laurentii Salvii, Holmiae, 12th ed., Vol. 1(1): 532 p.

Livingstone, D. A. 1953. The fresh water fishes of Nova Scotia. Proc. Nova Scotian Inst. Sci. 23(1): 90 p.

Loch, J. S. MS 1969. A description and general biology of the northern pearl dace, *Semotilus margarita nachtriebi*, with an introductory discussion of taxonomic principles. Dep. Zool. Univ. Toronto, Toronto, Ont. 34 p. + 7 fig (Mimeo.)

Lockington, W. N. 1880. Description of a new fish from Alaska (*Uranidea microstoma*). Proc. U.S. Nat. Mus. 3: 58–59.

Loeb, H. A. 1955. An electrical device for carp control. N.Y. Fish Game J. 2(2): 220–231.

—— 1960a. Reactions of carp to food and flavours. N.Y. Fish Game J. 7(1): 60–71.

—— 1960b. The development of stomach poisons for the control of carp. Contrib. Fed. Aid Fish Wildlife Restoration Proj. F-9-R, N.Y. State Conserv. Dep. 6 p. (Mimeo.)

Loftus, K. H. 1958. Studies on river spawning populations of lake trout in eastern Lake Superior. Trans. Amer. Fish. Soc. 87 (1957): 259–277.

Lord, J. K. 1866a. The naturalist in Vancouver Island and British Columbia. Vol. 1: 358 p. Richard Bentley, London.

—— 1866b. The naturalist in Vancouver Island and British Columbia. Vol. 2: 375 p. Richard Bentley, London.

—— 1867. A new charr (*Fario lordii*) from British Columbia. Intell. Observ. 10: 338–347.

Lorz, H. W., and T. G. Northcote. 1965. Factors affecting stream location, and timing and intensity of entry by spawning kokanee (*Oncorhynchus nerka*) into an inlet of Nicola Lake, British Columbia. J. Fish. Res. Board Canada 22(3): 665–687.

Loudon, W. J. 1910. The small-mouthed bass. Hunter-Rose Co. Ltd., Toronto, Ont. 103 p.

Low, A. P. 1896. Report on explorations in the Labrador Peninsula along the East Main, Koksoak, Hamilton, Manicugan and portions of other rivers in 1892–93–94–95. *In* Rep. Geol. Survey Canada, n.s. Vol. 8 for 1875, App. III. Queen's Printer, Ottawa, Ont. 387 p.

Lower, A. R. M. 1915. A report on the fish and fisheries of the West coast of James Bay, p. 29–67. *In* Canada. Dep. of the Naval Services. Report on fisheries investigations in Hudson and James Bays and tributary waters in 1914. King's Printer, Ottawa, Ont.

Lund, W. A., Jr. 1957. Morphometric study of the striped bass, *Roccus saxatilis*. U.S. Fish Wildlife Serv. Spec. Sci. Rep. Fish. 216: 24 p.

Lynch, J. E. 1936. New species of *Neoechinorhynchus* from the western sucker *Catostomus macrocheilus* Girard. Trans. Amer. Microsc. Soc. 55(1): 21–43.

Lyster, L. L. 1940a. Parasites of freshwater fish. II. Parasitism of speckled and lake trout and the fish found associated with them in Lake Commandant, Que. Can. J. Res., D, 18: 66–78.

—— 1940b. *Apophallus imperator* sp. nov., a heterophyid encysted in trout, with a contribution to its life history. Can. J. Res., D, 18: 106–121.

MacCrimmon, H. R. 1971. World distribution of rainbow trout (*Salmo gairdneri*). J. Fish. Res. Board Canada 28(5): 663–704.

MacCrimmon, H. R., and J. S. Campbell. 1969. World distribution of brook trout, *Salvelinus fontinalis*. J. Fish. Res. Board Canada 26(7): 1699–1725.

MacCrimmon, H. R., and W.-H. Kwain. 1969. Influence of light on early development and meristic characters in the rainbow trout, *Salmo gairdneri* Richardson. Can. J. Zool. 47(4): 631–637.

MacCrimmon, H. R., and T. L. Marshall. 1968. World distribution of brown trout, *Salmo trutta*. J. Fish. Res. Board Canada 25(12): 2527–2548.

MacCrimmon, H. R., T. L. Marshall, and B. L. Gots. 1970. World distribution of brown trout, *Salmo trutta*: further observations. J. Fish. Res. Board Canada 27(4): 811–818.

MacCrimmon, H. R., and E. Skobe. 1970. The fisheries of Lake Simcoe. Ont. Dep. Lands Forests, Toronto. 140 p.

MacKay, H. H. 1934. Record of the alewife from Lake Huron. Copeia (1934) 2: 97.

—— 1963. Fishes of Ontario. Ont. Dep. Lands Forests, Toronto. 300 p.

MacKay, H. H., and E. MacGillivray. 1949. Recent investigations on the sea lamprey, *Petromyzon marinus*, in Ontario. Trans. Amer. Fish. Soc. 76 (1946): 148–159.

Mackay, I., and G. Power. 1968. Age and growth of round whitefish (*Prosopium cylindraceum*) from Ungava. J. Fish. Res. Board Canada 25(4): 657–666.

MacLulich, D. A. 1943a. *Proteocephalus parallacticus*, a new species of tapeworm from lake trout, *Cristivomer namaycush*. Can. J. Res., D, 21: 145–149.

—— 1943b. Parasites of trout in Algonquin Provincial Park, Ontario. Can. J. Res., D, 21: 405–412.

Magnin, Étienne. 1959. Répartition actuelle des acipenserides. Rev. Trav. Inst. Pêches marit. 23(3): 277–285.

—— 1963a. Notes sur la répartition, la biologie et particulièrement la croissance de l'*Acipenser brevirostris* LeSueur 1817. Natur. Can. 90(3): 87–96.

—— 1963b. Recherches sur la systématique et la biologie des Acipenserides *Acipenser sturio* L., *Acipenser oxyrhynchus* Mitchill, *Acipenser fulvescens* Raf. Thèse de Docteur ès Sciences Naturelles, Université de Paris. Imprimerie Nationale, Sér. A., No. 3964, Paris. 242 p.

—— 1964. Validité d'une distinction spécifique entre les deux acipenseridés: *Acipenser sturio* L. d'Europe et *Acipenser oxyrhynchus* d'Amérique du nord. Natur. Can. 91(1): 5–20.

—— 1966a. Quelques données biologiques sur la reproduction des esturgeons *Acipenser fulvescens* Raf. de la Rivière Nottaway, tributaire de la Baie James. Can. J. Zool. 44(2): 257–263.

—— 1966b. Recherches sur les cycles de reproduction des esturgeons *Acipenser fulvescens* Raf. de la rivière Nottaway tributaire de la baie James. Verh. Internat. Verein. Limnol. 16: 1018–1024.

Magnin, É., et G. Beaulieu. 1966. Divers aspects de la biologie et de l'écologie de la barbue *Ictalurus punctatus* (Rafinesque) du fleuve Saint-Laurent d'après les données du marquage. Trav. Pêcheries Que. 92(12): 277–291.

—— 1967. Le bar, *Roccus saxatilis* (Walbaum), du Fleuve Saint-Laurent. Natur. Can. 94: 539–555.

—— 1968. Déplacements du doré jaune *Stizostedion vitreum* (Mitchill) du fleuve Saint-Laurent d'après les données du marquage. Natur. Can. 95: 897–905.

Magnuson, J. L., and L. L. Smith. 1963. Some phases of the life history of the trout-perch. Ecology 44(1): 83–95.

Maher, F. P., and P. A. Larkin. 1955. Life history of the steelhead trout of the Chilliwack River, British Columbia. Trans. Amer. Fish. Soc. 84 (1954): 27–38.

Mahon, E. F., and W. S. Hoar. 1956. The early development of the chum salmon, *Oncorhynchus keta* (Walbaum). J. Morphol. 98(1): 1–48.

Maloney, J. E., D. R. Schupp, and W. J. Scidmore. 1962. Largemouth bass population and harvest, Gladstone Lake, Crow Wing County, Minnesota. Trans. Amer. Fish. Soc. 91(1): 42–52.

Maloy, C. R., and H. Willoughby. 1967. Rearing marketable channel catfish in ponds. U.S. Fish Wildlife Serv. Resource Publ. 31: 4 p.

Mansell, W. D. 1966. Brown trout in southwestern Ontario. Ont. Fish Wildlife Rev. 5(2): 3–8.

Mansueti, A. J. 1964. Early development of the yellow perch, *Perca flavescens*. Chesapeake Sci. 5(1–2): 46–66.

Mansueti, A. J., and J. D. Hardy, Jr. 1967. Development of fishes of the Chesapeake Bay Region. Part 1. Nat. Res. Inst., Univ. Maryland, Baltimore, Md. 202 p.

Mansueti, R. J. 1956. Alewife herring eggs and larvae reared successfully in lab. Md. Tidewater News 13(1): 2–3, 1 fig.

—— 1960. Selection of body site for scale samples in the white perch, *Roccus americanus*. Chesapeake Sci. 1(2): 103–109.

—— 1961. Movements, reproduction, and mortality of the white perch, *Roccus americanus*, in the Patuxent estuary, Maryland. Chesapeake Sci. 2(3–4): 142–205.

Marcotte, A., et J.-L. Tremblay. 1948. Notes sur la biologie de l'éperlan (*Osmerus mordax*, Mitchill) de la province de Québec. Contrib. Station Biol. Saint-Laurent, P.Q. 18: 107 p.

Margolis, L. 1951. "Red sore" disease of pike in Mont Tremblant Park District, Quebec. Can. Fish Cult. 10: 30–31.

—— 1954. Ulcer disease and furunculosis in a Quebec trout hatchery. Can. Fish Cult. 15: 16–17.

—— 1963. Parasites as indicators of the geographical origin of sockeye salmon, *Oncorhynchus nerka* (Walbaum), occurring in the North Pacific Ocean and adjacent seas. Int. North Pac. Fish. Comm. Bull. 11: 101–156.

—— 1965. Parasites as an auxiliary source of information about the biology of Pacific salmons (genus *Oncorhynchus*). J. Fish. Res. Board Canada 22(6): 1387–1395.

—— 1967a. *Triaenophorus crassus* plerocercoids in sockeye salmon smolts from the Kvichak River system, Alaska. J. Fish. Res. Board Canada 24(4): 893–894.

—— 1967b. The swimbladder nematodes (Cystidicolinae) of Pacific salmons (genus *Oncorhynchus*). Can. J. Zool. 45(6), pt. 2: 1183–1199.

Margolis, L., and J. R. Adams. 1956. Description of *Genolinea oncorhynchi* n.sp. (Trematoda: Hemiuridae) from *Oncorhynchus gorbuscha* in British Columbia with notes on the genus. Can. J. Zool. 34(6): 573–577.

Margolis, L., F. C. Cleaver, Y. Fukuda, and H. Godfrey. 1966. Salmon of the North Pacific Ocean — Part 6. Sockeye salmon in offshore waters. Int. North Pac. Fish. Comm. Bull. 20: 1–70.

Markus, H. C. 1934. Life history of the blackhead minnow (*Pimephales promelas*). Copeia 1934(3): 116–122.

Marshall, K. E., and J. J. Keleher. 1970. A bibliography of the lake trout, *Cristivomer namaycush* (Walbaum) 1929–1969. Fish. Res. Board Canada Tech. Rep. 176: 60 p.

Marshall, T. L., and H. R. MacCrimmon. 1970. Exploitation of self-sustaining Ontario stream populations of brown trout (*Salmo trutta*) and brook trout (*Salvelinus fontinalis*). J. Fish. Res. Board Canada 27(6): 1087–1102.

Martens, E. 1868. Ueber einige ostasiatische Susswasserthiere. Arch. Naturgesch. 34. Jahrg. 1: 1–64.

Martin, N. V. 1952. A study of the lake trout, *Salvelinus namaycush*, in two Algonquin Park, Ontario, lakes. Trans. Amer. Fish. Soc. 81 (1951): 111–137.

—— 1954. Catch and winter food of lake trout in certain Algonquin Park lakes. J. Fish. Res. Board Canada 11(1): 5–10.

—— 1955. The effect of drawdowns on lake trout reproduction and the use of artificial spawning beds. Trans. N. A. Wildlife Conf. 20: 263–271.

—— 1957. Reproduction of lake trout in Algonquin Park, Ontario. Trans. Amer. Fish. Soc. (1956) 86: 231–244.

—— 1960. Homing behavior in spawning lake trout. Can. Fish Cult. 26: 3–6.

—— 1966. The significance of food habits in the biology, exploitation, and management of Algonquin Park, Ontario, lake trout. Trans. Amer. Fish. Soc. 95(4): 415–422.

—— 1970. Long-term effects of diet on the biology of the lake trout and the fishery in Lake Opeongo, Ontario. J. Fish. Res. Board Canada 27(1): 125–146.

Martin, N. V., and N. S. Baldwin. 1960. Observations on the life history of the hybrid between eastern brook trout and lake trout in Algonquin Park, Ontario. J. Fish. Res. Board Canada 17(4): 541–551.

Martin, N. V., and L. J. Chapman. 1965. Distribution of certain crustaceans and fishes in the region of Algonquin Park, Ontario. J. Fish. Res. Board Canada 22(4): 969–976.

Martin, N. V., and F. K. Sandercock. 1967. Pyloric caeca and gill raker development in lake trout, *Salvelinus namaycush*, in Algonquin Park, Ontario. J. Fish. Res. Board Canada 24(5): 965–974.

Martin, W. R. MS 1939. The Arctic char of North America. M.Sc. Thesis. Univ. Toronto, Toronto, Ont. 64 p.

Marzolf, R. C. 1955. Use of pectoral spines and vertebrae for determining age and rate of growth of the channel catfish. J. Wildlife Manage. 19(2): 243–249.

Mason, E. J. R. 1933. Smelts in Lake Ontario. Copeia 1933(1): 34.

Mason, J. E. 1965. Salmon of the North Pacific Ocean — Part 9. Coho, chinook and masu salmon in offshore waters. 2. Chinook salmon in offshore waters. Int. North Pac. Fish. Comm. Bull. 16: 41–73.

Maxfield, G. H. 1967. Pacific salmon literature compilation — 1900–59. U.S. Dep. Comm., Clearinghouse Fed. Sci. Tech. Inform. doc. PB 174 102: 645 microfiches (42,341 p.).

Mayhew, J. 1956. The bluegill, *Lepomis macrochirus* (Rafinesque) in West Okoboji Lake, Iowa. Proc. Iowa Acad. Sci. 63: 705–713.

McAfee, W. R. 1966. Eastern brook trout. Calif. Dep. Fish Game, Inland Fish. Manage. A. Calhoun [ed.]. p. 242–260.

McAllister, D. E. 1959. Records of marine fishes from fresh water in British Columbia. Can. Field-Natur. 73(1): 13–14.

—— 1961. The origin and status of the deepwater sculpin, *Myoxocephalus thompsonii*, a nearctic glacial relict. Bull. Nat. Mus. Canada Contrib. Zool. (1959) 172: 44–65.

—— 1962a. The brassy minnow, river shiner and sauger new to Alberta. Can. Field-Natur. 76(2): 124–125.

—— 1962b. Fishes of the 1960 "Salvelinus" program from western Arctic Canada. Bull. Nat. Mus. Canada Contrib. Zool. 185: 17–39.

—— 1963. A revision of the smelt family, Osmeridae. Bull. Nat. Mus. Canada 191, Biol. Ser. 71: 53 p.

—— 1964a. Distinguishing characters for the sculpins *Cottus bairdii* and *C. cognatus* in eastern Canada. J. Fish. Res. Board Canada 21(5): 1339–1342.

—— 1964b. Fish collections from eastern Hudson Bay. Can. Field-Natur. 78(3): 167–178.

—— 1968. Evolution of branchiostegals and classification of teleostome fishes. Bull. Nat. Mus. Canada 221, Biol. Ser. 77: 239 p.

—— 1969. Introduction of tropical fishes into a hotspring near Banff, Alberta. Can. Field-Natur. 83(1): 31–35.

—— 1970. Rare or endangered Canadian fishes. Can. Field-Natur. 84(1): 5–8.

McAllister, D. E., and S. Bleakney. 1960. Some freshwater fishes from northeastern Quebec and Labrador. Bull. Nat. Mus. Canada Contrib. Zool. (1958) 166: 31–39.

McAllister, D. E., and C. C. Lindsey. 1961. Systematics of the freshwater sculpins (*Cottus*) of British Columbia. Bull. Nat. Mus. Canada Contrib. Zool. (1959) 172: 66–89.

McCabe, B. C. 1942. Fishes. Section 3: Fish. Surv. Rep. Mass. Dep. Conserv. Div. Fish Game. p. 3–68.

—— 1958. *Esox niger* LeSueur. Tabular treatment of the life history and ecology of the chain pickerel. Nat. Acad. Sci. Comm. Handb. Biol. Data. 45 p. (Mimeo.)

McCann, J. A. 1959. Life history studies of the spottail shiner of Clear Lake, Iowa, with particular reference to some sampling problems. Trans. Amer. Fish. Soc. 88(4): 336–343.

McCarraher, D. B., and R. Thomas. 1968. Some ecological observations on the fathead minnow, *Pimephales promelas*, in the alkaline waters of Nebraska. Trans. Amer. Fish. Soc. 97(1): 52–55.

McCart, P. 1965. Growth and morphometry of four British Columbia populations of pygmy whitefish (*Prosopium coulteri*). J. Fish. Res. Board Canada 22(5): 1229–1259.

—— 1970. Evidence for the existence of sibling species of pygmy whitefish (*Prosopium coulteri*) in three Alaskan lakes, p. 81–98. *In* C. C. Lindsey and C. S. Woods [ed.] Biology of coregonid fishes. Univ. Manitoba Press, Winnipeg, Man. 560 p.

McCart, P., and B. Andersen. 1967. Plasticity of gillraker number and length in *Oncorhynchus nerka*. J. Fish. Res. Board Canada 24(9): 1999–2002.

McClane, A. J. [ed.] 1965. McClane's standard fishing encyclopedia and international angling guide. Holt, Rinehart and Winston, N.Y. 1057 p.

McComish, T. S. 1968. Sexual differentiation of bluegills by the urogenital opening. Progr. Fish-Cult. 30(1): 28.

McConnell, W. J. 1952. The opercular bone as an indicator of age and growth of the carp, *Cyprinus carpio* Linnaeus. Trans. Amer. Fish. Soc. 81 (1951): 138–149.

McCraw, B. M. 1952. Furunculosis of fish. U.S. Fish Wildlife Serv. Spec. Sci. Rep. Fish. 84: 87 p.

McCrimmon, H. R. 1948. The reintroduction of Atlantic salmon into tributary streams of Lake Ontario. Trans. Amer. Fish. Soc. 78 (1948): 128–132.

—— 1952. Mortality of coregonid fish in Lake Simcoe during spring temperature warm-up. Can. Field-Natur. 66(4): 112.

—— 1954. Stream studies on planted Atlantic salmon. J. Fish. Res. Board Canada 11(4): 362–403.

—— 1956. Fishing in Lake Simcoe. Ont. Dep. Lands Forests, Toronto. 137 p.

—— 1958. Observations on the spawning of lake trout, *Salvelinus namaycush*, and the post-spawning movement in Lake Simcoe. Can. Fish Cult. 23: 3–11.

—— 1968. Carp in Canada. Fish. Res. Board Canada Bull. 165: 93 p.

McCrimmon, H. R., and O. E. Devitt. 1954. Winter studies on the burbot, *Lota lota lacustris*, of Lake Simcoe, Ontario. Can. Fish Cult. 16: 34–41.

McCrimmon, H. R., and U. B. Swee. 1967. Scale formation as related to growth and development of young carp, *Cyprinus carpio* L. J. Fish. Res. Board Canada 24(1): 47–51.

McFadden, J. T., and E. L. Cooper. 1964. Population dynamics of brown trout in different environments. Physiol. Zool. 37(4): 355–363.

McFadden, J. T., E. L. Cooper, and J. K. Andersen. 1962. Sex ratio in wild populations of brown trout. Trans. Amer. Fish. Soc. 91(1): 94–95.

—— 1965. Some effects of environment on egg production in brown trout (*Salmo trutta*). Limnol. Oceanogr. 10(1): 88–95.

McHugh, J. L. 1940. Food of the Rocky Mountain whitefish, *Prosopium williamsoni* (Girard). J. Fish. Res. Board Canada 5(2): 131–137.

—— 1942. Growth of the Rocky Mountain whitefish. J. Fish. Res. Board Canada 5(4): 337–343.

McInerney, J. E. 1969. Reproductive behavior of the blackspotted stickleback, *Gasterosteus wheatlandi*. J. Fish. Res. Board Canada 26(8): 2061–2075.

McIntyre, J. D. 1969. Spawning behavior of the brook lamprey, *Lampetra planeri*. J. Fish. Res. Board Canada 26(12): 3252–3254.

McKenzie, J. A., and M. H. A. Keenleyside. 1970. Reproductive behavior of ninespine sticklebacks (*Pungitius pungitius* (L.)) in South Bay, Manitoulin Island, Ontario. Can. J. Zool. 48(1): 55–61.

McKenzie, R. A. 1947. The Prairie "jigger" for setting gill nets under ice. Fish. Res. Board Canada Circ. Gen. Ser. 7. (2 p. unnumbered).

—— 1959. Marine and freshwater fishes of the Miramichi River and estuary, New Brunswick. J. Fish. Res. Board Canada 16(6): 807–833.

—— 1964. Smelt life history and fishery in the Miramichi River, New Brunswick. Fish. Res. Board Canada Bull. 144: 77 p.

McLain, A. L. 1952. Diseases and parasites of the sea lamprey, *Petromyzon marinus*, in the Lake Huron basin. Trans. Amer. Fish. Soc. 81 (1951): 94–100.

McLarney, W. O. 1968. Spawning habits and morphological variation in the coastrange sculpin, *Cottus aleuticus*, and the prickly sculpin, *Cottus asper*. Trans. Amer. Fish. Soc. 97(1): 46–48.

McMurrich, J. P. 1909. The life history of the Pacific salmon. Trans. Can. Inst. Toronto 9: 23–44.

McMynn, R. G., and P. A. Larkin. 1953. The effects on fisheries of present and future water utilization in the Campbell River drainage area. Brit. Columbia Game Comm. Manage. Publ. 2: 61 p.

McPhail, J. D. 1960. Annotated bibliography on arctic North American fresh-water fishes. Univ. British Columbia Inst. Fish. Mus. Contrib. 6: 1–24.

—— 1961. A systematic study of the *Salvelinus alpinus* complex in North America. J. Fish. Res. Board Canada 18(5): 793–814.

—— 1963. Geographic variation in North American ninespine sticklebacks, *Pungitius pungitius*. J. Fish. Res. Board Canada 20(1): 27–44.

—— 1966. The *Coregonus autumnalis* complex in Alaska and northwestern Canada. J. Fish. Res. Board Canada 23(1): 141–148.

—— 1967. Distribution of freshwater fishes in western Washington. Northwest Sci. 41(1): 1–11.

McPhail, J. D., and C. C. Lindsey. 1970. Freshwater fishes of northwestern Canada and Alaska. Fish. Res. Board Canada Bull. 173: 381 p.

Medcof, J. C. 1966. Incidental records on behaviour of eels in Lake Ainslie, Nova Scotia. J. Fish. Res. Board Canada 23(7): 1101–1105.

Meek, S. E. 1888. The fishes of the Cayuga Lake basin. Ann. N.Y. Acad. Sci. 4: 297–316.

—— 1899. Notes on a collection of fishes and amphibians from Muskoka and Gull Lakes. Field Columbian Mus. Publ. 41, Zool. ser. 1(17): 307–311.

Meek, S. E., and H. W. Clark. 1902. Notes on a collection of cold-blooded vertebrates from Ontario. Field Columbian Mus. Publ. 67, Zool. ser. 3(7): 131–140.

Mélançon, C. 1936. Les poissons de nos eaux. 2nd ed. Montreal, Que. 250 p.

Melvill, C. D. 1915. Report on the east coast fisheries of James Bay. Ann. Rep. Canada Dep. Naval Serv. 1913–14: 3–29 of appendix.

Melville, J. C. D. 1914. Notes on the distribution and economic importance of the 'inconnu' (*Stenodus mackenzii*) in the Mackenzie River valley. 47th Ann. Rep. Dep. Mar. Fish. Ottawa. p. 238–240.

Merriman, D. 1941. Studies on the striped bass (*Roccus saxatilis*) of the Atlantic Coast. U.S. Fish Wildlife Serv. Fish. Bull. 35, Vol. 50: 1–77.

Metcalf, A. L. 1966. Fishes of the Kansas River System in relation to zoogeography of the Great Plains. Univ. Kansas Publ. Mus. Natur. Hist. 17(3): 23–189, 4 figs., 51 maps.

Meyer, W. H. 1962. Life history of three species of redhorse (*Moxostoma*) in the Des Moines River, Iowa. Trans. Amer. Fish. Soc. 91(4): 412–419.

Migdalski, E. C. 1962. Angler's guide to the fresh water sport fishes. Ronald Press, N.Y. 431 p.

Miller, E. E. 1966. Channel catfish, p. 440–463. *In* Inland Fisheries Management. Calif. Dep. Fish Game Resources Agency.

Miller, J. G. 1962. Occurrence of ripe chain pickerel in the fall. Trans. Amer. Fish. Soc. 91(3): 323.

Miller, R. B. 1945. Studies on cestodes of the genus *Triaenophorus* from fish of Lesser Slave Lake, Alberta. Can. J. Res., D, 23: 117–127.

—— 1946a. Effectiveness of a whitefish hatchery. J. Wildlife Manage. 10(4): 316–322.

—— 1946b. Notes on the Arctic grayling, *Thymallus signifer* Richardson, from Great Bear Lake. Copeia 1946(4): 227–236.

—— 1947. Great Bear Lake, p. 31–44. *In* North West Canadian Fisheries Surveys in 1944–1945. Fish. Res. Board Canada Bull. 72: 94 p.

—— 1949. Preliminary biological surveys of Alberta watersheds, 1947–1949. Alberta Dep. Lands Forests. 139 p.

—— 1950. Observations on mortality rates in fished and unfished cisco populations. Trans. Amer. Fish. Soc. 79 (1949): 180–186.

—— 1954. Comparative survival of wild and hatchery-reared cutthroat trout in a stream. Trans. Amer. Fish. Soc. 83 (1953): 120–130.

—— 1956. The collapse and recovery of a small whitefish fishery. J. Fish. Res. Board Canada 13(1): 135–146.

—— 1957. Permanence and size of home territory in stream-dwelling cutthroat trout. J. Fish. Res. Board Canada 14(5): 687–691.

Miller, R. B., and W. A. Kennedy. 1946. Color change in a sculpin. Copeia 1946(2): 100.

—— 1948a. Observations on the lake trout of Great Bear Lake. J. Fish. Res. Board Canada 7(4): 176–189.

—— 1948b. Pike (*Esox lucius*) from four northern Canadian lakes. J. Fish. Res. Board Canada 7(4): 190–199.

Miller, R. B., and R. C. Thomas. 1957. Alberta's 'pothole' trout fisheries. Trans. Amer. Fish. Soc. 86 (1956): 261–268.

Miller, R. J. 1968. Speciation in the common shiner: an alternative view. Copeia 1968(3): 640–647.

Miller, R. R. 1950a. A review of the American clupeid fishes of the genus *Dorosoma*. Proc. U.S. Nat. Mus. 100(3267): 387–410.

—— 1950b. Notes on the cutthroat and rainbow trouts with the description of a new species from the Gila River, New Mexico. Occas. Pap. Mus. Zool. Univ. Mich. 529: 42 p. + 1 pl.

—— 1952. Bait fishes of the lower Colorado River from Lake Mead, Nevada, to Yuma, Arizona, with a key for their identification. Calif. Fish Game 38(1): 7–42.

—— 1954. The southern limit of the garfishes, family Lepisosteidae. Copeia 1954(3): 230–231.

—— 1957. Origin and dispersal of the alewife, *Alosa pseudoharengus*, and the gizzard shad, *Dorosoma cepedianum*, in the Great Lakes. Trans. Amer. Fish. Soc. 86 (1956): 97–111.

—— 1960. Systematics and biology of the gizzard shad (*Dorosoma cepedianum*) and related fishes. U.S. Fish Wildlife Serv. Fish. Bull. 173, Vol. 60: 371–392.

Miller, R. R., and R. G. Miller. 1948. The contribution of the Columbia River system to the fish fauna of Nevada: five species unrecorded from the State. Copeia 1948(3): 174–187.

Miller, R. R., and G. R. Smith. 1967. New fossil fishes from Plio-Pleistocene Lake Idaho. Occas. Pap. Mus. Zool. Univ. Mich. 654: 24 p.

Miller, R. V. 1968. A systematic study of the greenside darter, *Etheostoma blennioides* Rafinesque (Pisces: Percidae). Copeia 1968(1): 1–40.

Milne, D. J. 1964. The chinook and coho salmon fisheries of British Columbia. Fish. Res. Board Canada Bull. 142: 46 p. (appendix by H. Godfrey).

Milner, J. W. 1874. Notes on the grayling of North America. Rep. Commissioner for 1872 and 1873, U.S. Comm. Fish Fish. Pt. 2: 729–742.

Mitchill, S. L. 1814. Report in part of Samuel L. Mitchill, M.D., on the fishes of New York. D. Carlisle, N.Y. 28 p.

—— 1815a. Fishes of New York. Trans. Lit. Phil. Soc. N.Y. 1: 355–492.

—— 1815b. On the fishes of New York. Notice in Trans. Linn. Soc. London 1815, 11(2): 424.

—— 1817. Report on the ichthyology of the Walkill, from specimens of fishes presented to the Society (Lyceum of Natural History) by Dr. B. Akerly. Amer. Month. Mag. Crit. Rev. 1(4): 289–290.

—— 1818a. Memoir on ichthyology. The fishes of New York described and arranged. Amer. Month. Mag. Crit. Rev. 1817–1818, 2: 241–248; 321–328.

—— 1818b. Description of three species of fish. J. Acad. Natur. Sci. Philadelphia 1(2): 407–412.

Moffett, J. W. 1957. Recent changes in the deep-water fish populations of Lake Michigan. Trans. Amer. Fish. Soc. 86 (1956): 393–408.

—— 1966. The general biology of the cyclostomes with special reference to the lamprey, p. 252–262. *In* Phylogeny of immunity. Pt. 5. Univ. Florida Press, Gainesville, Fla. 276 p.

Moffett, J. W., and B. P. Hunt. 1943. Winter feeding habits of bluegills, *Lepomis macrochirus* Rafinesque, and yellow perch, *Perca flavescens* (Mitchill), in Cedar Lake, Washtenaw County, Michigan. Trans. Amer. Fish. Soc. 73 (1943): 231–242.

Montpetit, A. N. 1897. Les poissons d'eau douce du Canada. Montreal, Que. 553 p. + 12 pls.

Moodie, G. E. E. MS 1966. Some factors affecting the distribution and abundance of the chiselmouth (*Acrocheilus alutaceus*). M.Sc. Thesis. Dep. Zool., Univ. British Columbia, Vancouver, B.C. 53 p.

Moore, E. 1922. The primary sources of food of certain food and game and bait fishes of Lake George, p. 52–63 + 3 figs. *In* A biological survey of Lake George, N.Y. N.Y. Conserv. Comm.

—— 1930. A biological survey of the Champlain watershed. Suppl. to 19th Ann. Rept. N.Y. State Conserv. Dep. for 1929. Albany, N.Y. 321 p. + maps.

MOORE, G. A. 1968. Fishes, p. 21–165. *In* Vertebrates of the United States, by W. F. Blair, A. P. Blair, P. Brodkorb, F. R. Cagle, and G. A. Moore. 2nd ed. McGraw-Hill Inc. 616 p.

MOORE, H. R. 1917. The burbot. U.S. Bur. Fish. Econ. Circ. 25: 1–4.

MORRIS, D. 1958. The reproductive behaviour of the ten-spined stickleback (*Pygosteus pungitius* L.). Behaviour, Supp. 6. E. J. Brill, Leiden. 154 p.

MORROW, J. E. 1964. Populations of pike, *Esox lucius*, in Alaska and northeastern North America. Copeia 1964(1): 235–236.

MORSELL, J. W., and C. R. NORDEN. 1968. Food habits of the alewife, *Alosa pseudoharengus* (Wilson), in Lake Michigan. Proc. 11th Conf. Great Lakes Res. 1968. p. 96–102.

MORTON, W. M. 1970. On the validity of all subspecific descriptions of North American *Salvelinus malma* (Walbaum). Copeia 1970(3): 581–587.

MORTON, W. M., and R. R. MILLER. 1954. Systematic position of the lake trout, *Salvelinus namaycush*. Copeia 1954(2): 116–124.

MOSS, D. D., and D. C. SCOTT. 1961. Dissolved-oxygen requirements of three species of fish. Trans. Amer. Fish. Soc. 90(4): 377–393.

MOTTLEY, C. MCC. 1934. The origin and relations of the rainbow trout. Trans. Amer. Fish. Soc. 64 (1934): 323–327.

—— 1936a. The classification of the rainbow trout of British Columbia. Biol. Board Canada Progr. Rep. Pac. Biol. Sta. Pac. Fish. Exp. Sta. 27: 3–5.

—— 1936b. A biometrical study of the Kamloops trout of Kootenay Lake, *Salmo kamloops* Jordan. J. Biol. Board Canada 2(4): 359–377.

MRAZ, D. 1964a. Age and growth of the round whitefish (*Prosopium cylindraceum*) in Lake Michigan. Trans. Amer. Fish. Soc. 93(1): 46–53.

—— 1964b. Observations on large and smallmouth bass nesting and early life history. Wis. Conserv. Dep. Res. Rep. Fish 11: 13 p.

MRAZ, D., S. KMIOTEK, and L. FRANKENBERGER. 1961. The largemouth bass. Its life history, ecology and management. Wis. Conserv. Dep. Publ. 232: 13 p.

MRAZ, D., and C. W. THREINEN. 1957. Angler's harvest, growth rate and population estimate of the largemouth bass of Browns Lake, Wisconsin. Trans. Amer. Fish. Soc. 85 (1955): 241–256.

MUELLER, J. F. 1934. Pt. 4. Additional studies on parasites of Oneida Lake fishes including descriptions of new species, p. 335–373. *In* Parasites of Oneida Lake fishes. Bull. N.Y. State Coll. Forestry 7(1). Roosevelt Wild Life Annals 3(4).

MUNCY, R. J. 1962. Life history of the yellow perch, *Perca flavescens*, in estuarine waters of Severn River, a tributary of Chesapeake Bay, Maryland. Chesapeake Sci. 3(3): 143–159.

MUNRO, J. A., and W. A. CLEMENS. 1936. Food of the American merganser (*Mergus merganser americanus*) in British Columbia. Can. Field-Natur. 50(3): 34–36.

—— 1937. The American merganser in British Columbia and its relation to the fish population. Bull. Biol. Bd. Canada 55: 50 p.

MYERS, G. S. 1932. A new whitefish, *Prosopium snyderi*, from Crescent Lake, Washington. Copeia 1932(2): 62–64.

NARVER, D. W., and M. L. DAHLBERG. 1965. Estuarine food of Dolly Varden at Chignik, Alaska. Trans. Amer. Fish. Soc. 94(4): 405–408.

NASH, C. W. 1908. Manual of vertebrates of Ontario. Legislative Assembly Ont., Toronto, Ont. 107 p.

NEAVE, F. 1958. The origin and speciation of *Oncorhynchus*. Trans. Roy. Soc. Canada ser. 3, 52, sec. 5: 25–39.

—— 1966. Salmon of the North Pacific Ocean — Part 3. A review of the life history of North Pacific salmon. 6. Chum salmon in British Columbia. Int. North Pac. Fish. Comm. Bull. 18: 81–85.

NEAVE, F., and A. BAJKOV. 1929. Reports of the Jasper Park Lakes investigations, 1925–26. 5. Food and growth of Jasper Park fishes. Contrib. Can. Biol. Fish. n.s. 4(16): 199–217 + 1 pl.

NEEDHAM, J. G. 1920. Clean waters for New York State. Cornell Rural School Leafl. 13: 153–182.

NEEDHAM, P. R. 1938. Trout streams. Comstock Pub. Co., Ithaca, N.Y. 233 p.

—— 1961. Observations on the natural spawning of eastern brook trout. Calif. Fish Game 47(1): 27–40.

NEEDHAM, P. R., and R. GARD. 1959. Rainbow trout in Mexico and California. Univ. Calif. Publ. Zool. 67(1): 1–124 + pls. 1–8, figs., maps.

NEEDHAM, P. R., and T. M. VAUGHAN. 1952. Spawning of the Dolly Varden, *Salvelinus malma*, in Twin Creek, Idaho. Copeia 1952(3): 197–199.

NEEDLER, A. W. H. 1929. Unpigmented elvers (*Anguilla rostrata* LeSueur) in haddock stomachs at Ingonish, Cape Breton. Copeia 1929(171): 41–42.

—— 1939. A preliminary list of the fishes of Malpeque Bay. Proc. Nova Scotian Inst. Sci. 20(2): 33–41.

NEILL, W. T. 1950. An estivating bowfin. Copeia 1950(3): 240.

NELSON, E. W. 1876. A partial catalogue of the fishes of Illinois. Ill. Mus. Natur. Hist. Bull. 1(1): 33–52.

—— 1887. Field notes on Alaskan fishes. Rep. Natur. Hist. Coll. Alaska between years 1877 and 1881. 3: 297–322. Washington.

Nelson, J. S. 1965. Effects of fish introductions and hydroelectric development on fishes in the Kananaskis River system, Alberta. J. Fish. Res. Board Canada 22(3): 721–753.

—— 1968a. Salinity tolerance of brook sticklebacks, *Culaea inconstans*, freshwater ninespine sticklebacks, *Pungitius pungitius*, and freshwater fourspine sticklebacks, *Apeltes quadracus*. Can. J. Zool. 44(4): 663–667.

—— 1968b. Life history of the brook silverside, *Labidesthes sicculus*, in Crooked Lake, Indiana. Trans. Amer. Fish. Soc. 97(3): 293–296.

—— 1968c. Hybridization and isolating mechanisms between *Catostomus commersonii* and *C. macrocheilus* (Pisces: Catostomidae). J. Fish. Res. Board Canada 25(1): 101–150.

—— 1968d. Distribution and nomenclature of North American kokanee, *Oncorhynchus nerka*. J. Fish. Res. Board Canada 25(2): 409–414.

—— 1968e. Variation in gillraker number in North American kokanee, *Oncorhynchus nerka*. J. Fish. Res. Board Canada 25(2): 415–420.

—— 1969. Geographic variation in the brook stickleback, *Culaea inconstans*, and notes on nomenclature and distribution. J. Fish. Res. Board Canada 26(9): 2431–2447.

—— 1971a. Comparison of the pectoral and pelvic skeletons and of some other bones and their phylogenetic implications in the Aulorhynchidae and Gasterosteidae (Pisces). J. Fish. Res. Board Canada 28(3): 427–442.

—— 1971b. Absence of the pelvic complex in ninespine sticklebacks, *Pungitius pungitius*, collected in Ireland and Wood Buffalo National Park Region, Canada, with notes on meristic variation. Copeia 1971(4): 707–717.

Nelson, J. S., and F. M. Atton. 1971. Geographic and morphological variation in the presence and absence of the pelvic skeleton in the brook stickleback, *Culaea inconstans* (Kirtland), in Alberta and Saskatchewan. Can. J. Zool. 49(3): 343–352.

Nelson, W. R. 1968a. Reproduction and early life history of sauger, *Stizostedion canadense*, in Lewis and Clark Lake. Trans. Amer. Fish. Soc. 97(2): 159–166.

—— 1968b. Embryo and larval characteristics of sauger, walleye, and their reciprocal hybrids. Trans. Amer. Fish. Soc. 97(2): 167–174.

Netboy, A. 1968. The Atlantic salmon. A vanishing species? Faber and Faber, London. 457 p.

Netsch, Lt. Norval F., and A. Witt, Jr. 1962. Contributions to the life history of the longnose gar (*Lepisosteus osseus*) in Missouri. Trans. Amer. Fish. Soc. 91(3): 251–262.

New, J. G. 1962. Hybridization between two cyprinids, *Chrosomus eos* and *Chrosomus neogaeus*. Copeia 1962(1): 147–152.

Newman, H. H. 1907. Spawning behavior and sexual dimorphism in *Fundulus heteroclitus* and allied fish. Biol. Bull. (Woods Hole) 12(5): 314–345.

—— 1914. Modes of inheritance in teleost hybrids. J. Exp. Zool. 16: 447–499.

Niazi, A. D., and G. A. Moore. 1926. The Weberian apparatus of *Hybognathus placitus* and *H. nuchalis* (Cyprinidae). Southwest. Natur. 7(1): 41–50.

Nikol'skii, G. V. 1954. (Rev. 1961.) Special ichthyology. Nat. Sci. Found. Washington, D.C. and Smithsonian Inst. 538 p. (Trans. from Russian)

Noble, G. K. 1934. Sex recognition in the sunfish, *Eupomotis gibbosus* (Linné). Copeia (1934)4: 151–155.

Noble, R. L. 1965. Life history and ecology of western blacknose dace, Boone County, Iowa, 1963–1964. Iowa Acad. Sci. 72: 282–293.

Norden, C. R. 1961a. Comparative osteology of representative salmonid fishes, with particular reference to the grayling (*Thymallus arcticus*) and its phylogeny. J. Fish. Res. Board Canada 18(5): 679–791.

—— 1961b. The identification of larval yellow perch, *Perca flavescens* and walleye, *Stizostedion vitreum*. Copeia 1961(3): 282–288.

—— 1967. Development and identification of the larval alewife, *Alosa pseudoharengus* (Wilson), in Lake Michigan. Proc. 11th Conf. Great Lakes Res. 1967. p. 70–78. Internat. Assoc. Great Lakes Res.

—— 1968. Morphology and food habits of the larval alewife, *Alosa pseudoharengus* (Wilson), in Lake Michigan. Proc. 11th Conf. Great Lakes Res. 1968. p. 103–110. Internat. Assoc. Great Lakes Res.

—— 1970. Evolution and distribution of the genus *Prosopium*, p. 67–80. *In* C. C. Lindsey and C. S. Woods [ed.] Biology of coregonid fishes. Univ. Manitoba Press, Winnipeg, Man. 560 p.

Norman, J. R. 1963. A history of fishes. (2nd ed.) Rev. by P. H. Greenwood. Ernest Benn Ltd., London. 398 p.

Normandeau, D. A. 1969. Life history and ecology of the round whitefish *Prosopium cylindraceum* (Pallas), of Newfound Lake, Bristol, New Hampshire. Trans. Amer. Fish. Soc. 98(1): 7–13.

Norris, T. 1868. Remarks on a new species of *Osmerus*. Proc. Acad. Natur. Sci. Philadelphia 20: 93–94.

Northcote, T. G. 1954. Observations on the comparative ecology of two species of fish, *Cottus asper* and *Cottus rhotheus*, in British Columbia. Copeia 1954(1): 25–28.

—— 1957. A review of the life history and management of the mountain whitefish, *Coregonus williamsoni* Girard. Fish Manage. Div. Brit. Columbia Game Comm. 6 p. (Mimeo.)

Northcote, T. G., and G. F. Hartman. 1959. A case of "schooling" behavior in the prickly sculpin, *Cottus asper* Richardson. Copeia 1959(2): 156–158.

Northcote, T. G., and H. W. Lorz. 1966. Seasonal and diel changes in food of adult kokanee (*Oncorhynchus nerka*) in Nicola Lake, British Columbia. J. Fish. Res. Board Canada 23(8): 1259–1263.

Northcote, T. G., and R. J. Paterson. 1960. Relationship between number of pyloric caeca and length of juvenile rainbow trout. Copeia 1960(3): 248–250.

Northcote, T. G., S. N. Williscroft, and H. Tsuyuki. 1970. Meristic and lactate dehydrogenase genotype differences in stream populations of rainbow trout below and above a waterfall. J. Fish. Res. Board Canada 27(11): 1987–1995.

Nursall, J. R., and V. Lewin. 1964. The stonecat, *Noturus flavus*, newly recorded in Alberta. Can. Field-Natur. 78(2): 128–129.

Odell, T. T. 1934. The life history and ecological relationships of the alewife (*Pomolobus pseudoharengus* (Wilson)), in Seneca Lake, New York. Trans. Amer. Fish. Soc. 64: 118–126.

Oehmcke, A. A., L. Johnson, J. Klingbiel, and C. Wistrom. 1958. The Wisconsin muskellunge. Its life history, ecology, and management. Wis. Conserv. Dep. Publ. 225: 12 p.

Okada, Y. 1950–1960. Studies on the freshwater fishes of Japan. Prefectural Univ. Mie, Tsu, Mie Prefecture, Japan. 860 p. + pls. I–LXI; text-figs. 1–133, tables 1–185.

Okkelberg, P. 1922. Notes on the life-history of the brook lamprey, *Ichthyomyzon unicolor*. Occas. Pap. Mus. Zool. Univ. Mich. 125: 14 p.

Olson, D. E. 1958. Statistics of a walleye sport fishery in a Minnesota lake. Trans. Amer. Fish. Soc. 87 (1957): 52–72.

Olund, L. J., and F. B. Cross. 1961. Geographic variation in the North American cyprinid fish, *Hybopsis gracilis*. Univ. Kansas Pub. Mus. Natur. Hist. 13(7): 323–348.

Ostdiek, J. L., and R. M. Nardone. 1959. Studies on the Alaskan blackfish *Dallia pectoralis*. I. Habitat, size and stomach analyses. Amer. Midland Natur. 61(1): 218–229.

Paetz, M. J., and J. S. Nelson. 1968. Keys to the fishes of Alberta. Mus. Zool. Univ. Alberta, Edmonton, Alta. 25 p. (Mimeo.)

—— 1970. The fishes of Alberta. Govt. Alberta. Distrib. Queen's Printer, Edmonton, Alta. 281 p.

Pallas, P. S. 1776. Reise durch verschiedene Provinzen des Russischen Reichs (1768–74). Vol. 3. St. Petersburg.

—— 1814. Zoogeographia Rosso-Asiatica. Vol. 3. Petropoli. 423 p. + cxxv. (Date established by Opinion 212 of Int. Comm. Zool. Nomencl.)

Parker, G. H., and H. P. Brower. 1935. A nuptial secondary sex-character in *Fundulus heteroclitus*. Biol. Bull. (Woods Hole) 68(1): 4–6.

Parker, P. S., and R. E. Lennon. 1956. Biology of the sea lamprey in its parasitic phase. U.S. Fish Wildlife Serv. Res. Rep. 44: iii + 32 p.

Parsons, J. W. 1967. Contributions of year-classes of blue pike to the commercial fishery of Lake Erie, 1943–59. J. Fish. Res. Board Canada 24(5): 1035–1066.

Paterson, C. G. 1966. Life history notes on the goldeye, *Hiodon alosoides* (Rafinesque), in the North Saskatchewan River in Alberta. Can. Field-Natur. 80(4): 250–251.

—— 1969. Occurrence of *Coregonus artedii* and *C. zenithicus* in Barrow Lake, Alberta. J. Fish. Res. Board Canada 26(7): 1934–1939.

Patten, B. G. 1960. A high incidence of the hybrid *Acrocheilus alutaceum* × *Ptychocheilus oregonense*. Copeia 1960(1): 71–73.

—— 1962. Cottid predation upon salmon fry in a Washington stream. Trans. Amer. Fish. Soc. 91(4): 427–429.

Patten, B. G., and D. T. Rodman. 1969. Reproductive behavior of northern squawfish, *Ptychocheilus oregonensis*. Trans. Amer. Fish. Soc. 98(1): 108–111.

Payne, N. R. MS 1964. The life history of the walleye, *Stizostedion vitreum vitreum* (Mitchill), in the Bay of Quinte. M.A. Thesis. Univ. Toronto, Toronto, Ont. 40 p.

Pearse, A. S. 1918. The food of the shore fishes of certain Wisconsin lakes. Bull. Bur. Fish. 35 (1915–16), doc. 856: 245–292.

—— 1919. Habits of the black crappie in inland lakes of Wisconsin. App. 3 Rep. U.S. Comm. Fish. (1918) Bur. Fish. Doc. 867: 5–16.

Pearson, J. C. 1938. The life history of the striped bass, or rockfish, *Roccus saxatilis* (Walbaum). U.S. Bur. Fish. Bull. 28(48): 825–851.

Peckham, R. S., and C. F. Dineen. 1957. Ecology of the central mudminnow, *Umbra limi* (Kirtland). Amer. Midland Natur. 58(1): 222–231.

Peer, D. L. 1966. Relationship between size and maturity in the spottail shiner, *Notropis hudsonius*. J. Fish. Res. Board Canada 23(3): 455–457.

Pennant, T. 1784. Arctic zoology. Vol. 1. Henry Hughes, London. 185 p.

—— 1792. Arctic zoology. 2nd ed. London 1(1): 1–334; 2: 1–418.

PERLEY, M. H. 1852. Reports of the sea and river fisheries of New Brunswick. Fredericton, N.B. 294 p.

PERLMUTTER, A. 1951. An aquarium experiment on the American eel as a predator on larval lampreys. Copeia 1951(2): 173–174.

—— 1963. Observations on fishes of the genus *Gasterosteus* in the waters of Long Island, New York. Copeia 1963(1): 168–173.

PETRAVICZ, J. J. 1936. The breeding habits of the least darter *Microperca punctulata* Putnam. Copeia 1936(2): 77–82.

PETRAVICZ, W. P. 1938. The breeding habits of the black-sided darter, *Hadropterus maculatus* Girard. Copeia 1938(1): 40–44.

PFEIFFER, REV. R. A. 1955. Studies on the life history of the rosyface shiner, *Notropis rubellus*. Copeia 1955(2): 95–104.

PFEIFFER, W., and T. F. PLETCHER. 1964. Club cells and granular cells in the skin of lamprey. J. Fish. Res. Board Canada 21(5): 1083–1088.

PFLIEGER, W. L. 1971. A distributional study of Missouri fishes. Univ. Kansas Publ. Mus. Natur. Hist. 20(3): 225–570, 15 figs., 193 maps.

PIAVIS, G. N. 1961. Embryological stages in the sea lamprey and effects of temperature on development. U.S. Fish Wildlife Serv. Fish. Bull. 182, Vol. 61: 111–143.

PIERS, H. 1927. *Coregonus labradoricus*, the Sault whitefish, an interesting addition to the freshwater fish fauna of Nova Scotia. Trans. Nova Scotian Inst. Sci. 16(2): 92–95.

PIGEON, J., et A. VALLÉE. 1937. Contenu du tube digestif de trois espèces de poissons du St-Laurent. Natur. Can. 64(2): 33–40.

PIKE, G. C. 1951. Lamprey marks on whales. J. Fish. Res. Board Canada 8(4): 275–280.

—— 1953. The Pacific sea lamprey. Fish. Res. Board Canada Progr. Rep. Pac. 97: 3–5.

PIPPY, J. H. C., and I. M. SANDEMAN. 1967. A kill of brook trout (*Salvelinus fontinalis*) involving the acanthocephalan *Echinorhynchus lateralis*. J. Fish. Res. Board Canada 24(7): 1627–1628.

PLETCHER, F. T. MS 1963. The life history and distribution of lampreys in the Salmon and certain other rivers in British Columbia, Canada. M.Sc. Thesis. Univ. British Columbia, Vancouver, B.C. 195 p.

POTTER, G. E. 1925. Scales of the bluegill, *Lepomis pallidus* (Mitchell). Trans. Amer. Microsc. Soc. 44: 31–37.

POWER, G. 1958. The evolution of freshwater races of the Atlantic salmon (*Salmo salar* L.). Arctic 2(2): 86–92.

—— 1965. Notes on the cold-blooded vertebrates of the Nabisipi River region, County Duplessis, Quebec. Can. Field-Natur. 79(1): 49–64.

—— 1966. Observations on the speckled trout (*Salvelinus fontinalis*) in Ungava. Natur. Can. 93(3): 187–199.

—— 1969. The salmon of Ungava Bay. Arctic Inst. North America Tech. Pap. 22: 72 p.

POWER, G., and D. R. OLIVER. 1961. Notes on the distribution and relative abundance of fresh-water fish in Ungava. Can. Field-Natur. 75(4): 221–224.

PRAKASH, A. 1962. Seasonal changes in feeding of coho and chinook (spring) salmon in southern British Columbia waters. J. Fish. Res. Board Canada 19(5): 851–866.

PREBLE, E. A. 1908. Fishes of the Athabaska-Mackenzie region, p. 502–515. *In* A biological investigation of the Athabaska-Mackenzie region. U.S. Dep. Agr. Bur. Biol. Surv. North American Fauna 27.

PRICE, C. E., and H. P. ARAI. 1967. The monogenean parasites of Canadian freshwater fishes. Can. J. Zool. 45(6), pt. 2: 1235–1245.

PRICE, J. W. 1940. Time–temperature relations in the incubation of the whitefish, *Coregonus clupeaformis* (Mitchill). J. Gen. Physiol. 23: 449–468.

PRIEGEL, G. R. 1963a. Dispersal of the shortnose gar, *Lepisosteus platostomus*, into the Great Lakes drainage. Trans. Amer. Fish. Soc. 92(2): 178.

—— 1963b. Food of walleye and sauger in Lake Winnebago, Wisconsin. Trans. Amer. Fish. Soc. 92(3): 312–313.

—— 1964. Early scale development in the walleye. Trans. Amer. Fish. Soc. 93(2): 199–200.

—— 1966. Age–length and length–weight relationship of bullheads from Little Lake Butte des Mortes, 1959. Wis. Conserv. Dep. Res. Rep. Fish. 17: 6 p.

—— 1969. The Lake Winnebago sauger. Age, growth, reproduction, food habits and early life history. Tech. Bull. Wis. Dep. Natur. Res. 43: 63 p.

—— 1970. Reproduction and early life history of the walleye in the Lake Winnebago region. Tech. Bull. Wis. Dep. Natur. Res. 45: 105 p.

PRINCE, E. E. 1898. On the Esocidae (or Luciidae) of Canada. Rep. 67th Meeting Brit. Ass. Advancement Sci. 1897. p. 688.

PRITCHARD, A. L. 1929. The alewife (*Pomolobus pseudoharengus*) in Lake Ontario. Univ. Toronto Stud. Publ. Ont. Fish. Res. Lab. 38: 37–54.

—— 1930. Spawning habits and fry of the cisco (*Leucichthys artedi*) in Lake Ontario. Contrib. Can. Biol. Fish. Stud. Biol. Sta. Canada n.s., 6(9): 227–240.

—— 1931. Taxonomic and life history studies of the ciscoes of Lake Ontario. Univ. Toronto Stud. Biol. Ser. 35, Publ. Ont. Fish. Res. Lab. 41: 78 p.

—— 1936. Stomach content analyses of fishes preying upon the young of Pacific salmon during the fry migration at McClinton Creek, Masset Inlet, British Columbia. Can. Field-Natur. 50(6): 104–105.

—— 1940. The age of spring salmon in the commercial catches in British Columbia. Fish. Res. Board Canada Progr. Rep. Pac. 44: 9–11.

—— 1943. The age of chum salmon taken in the commercial catches of British Columbia. Fish. Res. Board Canada Progr. Rep. Pac. 54: 9–11.

Pritchard, A. L., and A. L. Tester. 1944. Food of spring and coho salmon in British Columbia. Fish. Res. Board Canada Bull. 65: 23 p.

Provancher, L'Abbé. 1875. Faune canadienne. Les poissons. Natur. Can. 7: 361–363.

—— 1876. Faune canadienne. Les poissons. Natur. Can. 8: 257–263.

Putnam, F. W. 1863. List of the fishes sent by the Museum to different institutions, in exchange for other specimens, with annotations. Bull. Mus. Comp. Zool. 1(1): 2–16.

—— 1866. Remarks on a supposed nondescript species of *Gasterosteus* from Massachusetts. Proc. Essex Inst. 5: 4.

Qadri, S. U. 1959. Some morphological differences between the subspecies of cutthroat trout, *Salmo clarkii clarkii* and *Salmo clarkii lewisi*, in British Columbia. J. Fish. Res. Board Canada 16(6): 903–922.

—— 1967. Morphological comparisons of three populations of the lake char, *Cristivomer namaycush*, from Ontario and Manitoba. J. Fish. Res. Board Canada 24(6): 1407–1411.

—— 1968. Growth and reproduction of the lake whitefish, *Coregonus clupeaformis*, in Lac la Ronge, Saskatchewan. J. Fish. Res. Board Canada 25(10): 2091–2100.

Rabb, L., and L. A. McDermott. 1962. Bacteriological studies of freshwater fish. II. Furunculosis in Ontario fish in natural waters. J. Fish. Res. Board Canada 19(6): 989–995.

Radforth, I. 1944. Some considerations on the distribution of fishes in Ontario. Contrib. Roy. Ont. Mus. Zool. 25: 1–116.

Rafinesque, C. S. 1817a. Additions to the observations on the sturgeons of North America. Amer. Month. Mag. Crit. Rev. 1(4): 288.

—— 1817b. First decade of new North American fishes. Amer. Month. Crit. Rev. 2(2): 120–121.

—— 1818a. Descriptions of two new genera of North American fishes, *Opsanus* and *Notropis*. Amer. Month. Mag. Crit. Rev. 2(3): 203–204.

—— 1818b. Second decade of new North American fishes. Amer. Month. Mag. Crit. Rev. 2(3): 204–206.

—— 1818c. Discoveries in natural history made during a journey through the western region of the United States. Amer. Month. Mag. Crit. Rev. 3(5): 354–356.

—— 1818d. Further account of discoveries in natural history made during a journey through the western region of the United States. Amer. Month. Mag. Crit. Rev. 4(1): 39–42.

—— 1818e. Description of three new genera of fluviatile fish, *Pomoxis*, *Sarchirus* and *Exoglossum*. J. Acad. Natur. Sci. Philadelphia 1(2): 417–422.

—— 1819. Prodrome de 70 nouveaux genres d'animaux découverts dans l'intérieur des Etats-Unis d'Amérique durant l'année 1818. J. Physique, Paris, 88: 417–429.

—— 1820a. Fishes of the Ohio. Western Rev. and Misc. Mag. 1: 361–377.

—— 1820b. Fishes of the River Ohio. Western Rev. and Misc. Mag. 2: 48–57; 169–177; 235–242; 299–307.

—— 1820c. Ichthyologia Ohiensis, or natural history of the fishes inhabiting the river Ohio and its tributary streams, preceded by a physical description of the Ohio and its branches. Lexington, Ky. 90 p.

—— 1820d. Description of the silures or catfishes of the river Ohio. Quart. J. Sci. Lit. Arts, Roy. Inst. London 9: 48–52.

Rahrer, J. F. 1965. Age, growth, maturity, and fecundity of "humper" lake trout, Isle Royale, Lake Superior. Trans. Amer. Fish. Soc. 94(1): 75–83.

Raney, E. C. 1939. The breeding habits of the silvery minnow, *Hybognathus regius* Girard. Amer. Midland Natur. 21(3): 674–680.

—— 1940a. The breeding behavior of the common shiner, *Notropis cornutus* (Mitchill). Zoologica 25(1): 1–14 + 4 pls.

—— 1940b. *Rhinichthys bowersi* from West Virginia a hybrid, *Rhinichthys cataractae* × *Nocomis micropogon*. Copeia 1940(4): 270–271.

—— 1940c. Comparison of the breeding habits of two subspecies of black-nosed dace, *Rhinichthys atratulus* (Hermann). Amer. Midland Natur. 23(2): 399–403.

—— 1942. Propagation of the silvery minnow (*Hybognathus nuchalis regius* Girard) in ponds. Trans. Amer. Fish. Soc. 71 (1941): 215–218.

—— 1949. Nests under water. Can. Natur. 11(3): 71–78.

—— 1952. The life history of the striped bass, *Roccus saxatilis* (Walbaum). Bull. Bingham Oceanogr. Collect. 14(1): 5–97.

—— 1957. Subpopulations of the striped bass, *Roccus saxatilis* (Walbaum), in the tributaries of the Chesapeake Bay. U.S. Fish Wildlife Serv. Spec. Sci. Rep. Fish. 208: 85–107.

—— 1965. Some pan fishes of New York. Inform. Leafl. N.Y. State Conserv. Dep. Div. Conserv. Educat. Apr.–May. 16 p.

Raney, E. C., and D. P. deSylva. 1953. Racial investigations of the striped bass, *Roccus saxatilis* (Walbaum). J. Wildlife Manage. 17(4): 495–509.

Raney, E. C., and E. A. Lachner. 1942. Studies of the summer food, growth, and movements of young yellow pike-perch, *Stizostedion v. vitreum*, in Oneida Lake, New York. J. Wildlife Manage. 6(1): 1–16.

—— 1943. Age and growth of johnny darters, *Boleosoma nigrum olmstedi* (Storer) and *Boleosoma longimanum* (Jordan). Amer. Midland Natur. 29(1): 229–238.

—— 1946. Age, growth, and habits of the hog sucker, *Hypentelium nigricans* (LeSueur), in New York. Amer. Midland Natur. 36(1): 76–86.

Raney, E. C., and D. A. Webster. 1940. The food and growth of the young of the common bullhead, *Ameiurus nebulosus nebulosus* (LeSueur), in Cayuga Lake, New York. Trans. Amer. Fish. Soc. 69 (1939): 205–209.

Raney, E. C., W. S. Woolcott, and A. G. Mehring. 1954. Migratory pattern and racial structure of Atlantic Coast striped bass. Trans. 19th N. Amer. Wildlife Conf. p. 376–396.

Rasquin, P. 1949. Spontaneous depigmentation in the catfish. Copeia 1949(4): 246–251.

Rausch, R. L. 1956. Studies on the helminth fauna of Alaska. XVIII. The description and occurrence of *Diphyllobothrium dalliae* N. sp. (Cestoda). Trans. Amer. Microsc. Soc. 75(2): 180–187.

Rawson, D. S. MS 1930(?)a. The past, present and future of fishing in Lake Simcoe. 8 p.

—— 1930b. The bottom fauna of Lake Simcoe and its role in the ecology of the lake. Univ. Toronto Stud. Biol. Ser. 34, Publ. Ont. Fish. Res. Lab. 40: 183 p. + 5 pls.

—— 1932. The pike of Waskesiu Lake, Saskatchewan. Trans. Amer. Fish. Soc. 62 (1932): 323–330.

—— 1938. Natural rearing enclosures for smallmouth black bass. Trans. Amer. Fish. Soc. 67 (1937): 96–104.

—— 1945. The experimental introduction of smallmouth black bass into lakes of the Prince Albert National Park, Saskatchewan. Trans. Amer. Fish. Soc. 73 (1943): 19–31.

—— 1947. Great Slave Lake, p. 45–68. *In* Northwest Canadian fisheries surveys in 1944–45 (various authors). Fish. Res. Board Canada Bull. 72: 94 p.

—— 1949. A check list of the fishes of Saskatchewan. Rep. Roy. Comm. Fish. Saskatchewan 1947. Regina, Sask. 8 p.

—— 1950. The grayling (*Thymallus signifer*) in northern Saskatchewan. Can. Fish Cult. 6: 3–10.

—— 1951. Studies of the fish of Great Slave Lake. J. Fish. Res. Board Canada 8(4): 207–240.

—— 1957. The life history and ecology of the yellow walleye, *Stizostedion vitreum*, in Lac la Ronge, Saskatchewan. Trans. Amer. Fish. Soc. 86 (1956): 15–37.

—— 1959. Limnology and fisheries of Cree and Wollaston lakes in northern Saskatchewan. Fish. Branch Dep. Natur. Res. Sask. Fish. Rep. 4: 73 p.

—— 1960. Five lakes on the Churchill River near Stanley, Saskatchewan. Fish. Branch Dep. Natur. Res. Sask. Fish. Rep. 5: 39 p.

—— 1961, The lake trout of Lac la Ronge, Saskatchewan. J. Fish. Res. Board Canada 18(3): 423–462.

Rawson, D. S., and C. A. Elsey. 1950. Reduction in the longnose sucker population of Pyramid Lake, Alberta, in an attempt to improve angling. Trans. Amer. Fish. Soc. 78 (1948): 13–31.

Rawson, D. S., and J. E. Moore. 1944. The saline lakes of Saskatchewan. Can. J. Res. 22: 141–201.

Reckahn, J. A. 1970. Ecology of young lake whitefish (*Coregonus clupeaformis*) in South Bay, Manitoulin Island, Lake Huron, p. 437–460. *In* C. C. Lindsey and C. S. Woods [ed.] Biology of coregonid fishes. Univ. Manitoba Press, Winnipeg, Man. 560 p.

Reed, E. B. 1962. Limnology and fisheries of the Saskatchewan River in Saskatchewan. Fish. Branch Dep. Natur. Res. Sask. Fish. Rep. 6: 48 p.

Reed, H. D. 1900. The structure of the poison glands of *Schilbeodes gyrinus*. Proc. Amer. Assoc. Adv. Sci. 49: 232–233.

—— 1907. The poison glands of *Noturus* and *Schilbeodes*. Amer. Natur. 41(489): 553–566.

—— 1924a. The morphology and growth of the spines of siluroid fishes. J. Morphol. 38: 431–451 + figs. 1–14.

—— 1924b. The morphology of the dermal glands in nematognathus fishes. Zeitschr. Morphol. und Anthropol. (Stuttgart) 24: 227–264 + pls. 8–15 (incl. figs. 1–32).

Reed, R. J. 1954. Hermaphroditism in the rosyface shiner, *Notropis rubellus*. Copeia 1954(4): 293–294.

—— 1957a. The prolonged spawning of the rosyface shiner, *Notropis rubellus* (Agassiz), in northwestern Pennsylvania. Copeia 1957(3): 250.

—— 1957b. Phases of the life history of the rosyface shiner, *Notropis rubellus*, in northwestern Pennsylvania. Copeia 1957(4): 286–290.

—— 1958. The early life history of two cyprinids, *Notropis rubellus* and *Campostoma anomalum pullum*. Copeia 1958(4): 325–327.

—— 1959. Age, growth, and food of the longnose dace, *Rhinichthys cataractae*, in northwestern Pennsylvania. Copeia 1959(2): 160–162.

—— 1964. Life history and migration patterns of Arctic grayling. Alaska Dep. Fish Game Res. Rep. 2: 30 p.

—— 1967. Age and growth of Prince of Wales, Alaska, Dolly Varden, *Salvelinus malma* (Walbaum), and rainbow trout, *Salmo gairdneri* Richardson. Trans. Amer. Fish. Soc. 96(2): 223–224.

Reeves, C. D. 1907. The breeding habits of the rainbow darter (*Etheostoma coeruleum* Storer), a study in sexual selection. Biol. Bull. (Woods Hole) 14: 35–59.

Regan, C. T. 1911. British freshwater fishes. Methuen and Co., London. 287 p.

Regier, H. A. 1962. Validation of the scale method for estimating age and growth of bluegills. Trans. Amer. Fish. Soc. 91(4): 362–374.

—— 1963a. Ecology and management of largemouth bass and golden shiners in farm ponds in New York. N.Y. Fish Game J. 10(2): 139–169.

—— 1963b. Ecology and management of channel catfish in farm ponds in New York. N.Y. Fish Game J. 10(2): 170–185.

Regier, H. A., V. C. Applegate, and R. A. Ryder. 1969. The ecology and management of the walleye in western Lake Erie. Great Lakes Fish. Comm. Tech. Rep. 15: 101 p.

Reid, H. 1930. A study of *Eupomotis gibbosus* (L.) as occurring in the Chamcook lakes, N.B. Contrib. Can. Biol. Fish. 5(16): 457–466.

Reighard, J. E. 1894. A biological examination of Lake St. Clair. Bull. Mich. Fish. Comm. 4: 1–41.

—— 1900. The breeding habits of the dog-fish, *Amia calva*. First Rep. Mich. Acad. Sci. (1894–1899): 133–137.

—— 1904. The natural history of *Amia calva* Linnaeus. (In Mark Anniversary Volume, no. 4: 57–109 + pl. and figs, New York, 1904.)

—— 1906. The breeding habits, development and propagation of the black bass (*Micropterus dolomieu* Lacépède and *Micropterus salmoides* Lacépède). Bull. Mich. Fish Comm. 7: 73 p. + 29 fig.

—— 1910. Methods of studying the habits of fishes with an account of the breeding habits of the horned dace. Bull. Bur. Fish. 28, doc. 710: 1111–1136 + pls. 114–120.

—— 1913. The breeding habits of the log-perch (*Percina caprodes*). Rep. Mich. Acad. Sci. 15: 104–105.

—— 1943. The breeding habits of the river chub, *Nocomis micropogon* (Cope). Pap. Mich. Acad. Sci. Arts Lett. 28 (1942): 397–423.

Reighard, J. E., and H. Cummins. 1916. Description of a new species of lamprey of the genus *Ichthyomyzon*. Occas. Pap. Mus. Zool. Univ. Mich. 31: 12 p. + 2 pls.

Reisman, H. M. 1963. Reproductive behaviour of *Apeltes quadracus*, including some comparisons with other gasterosteid fishes. Copeia 1963(1): 191–192.

—— 1968. Reproductive isolating mechanisms of the blackspotted stickleback, *Gasterosteus wheatlandi*. J. Fish. Res. Board Canada 25(12): 2703–2706.

Richardson, J. 1823. Notice of the fishes, p. 705–728. *In* Appendix to narrative of a journey to the shores of the Polar Sea in the years 1819, 1820, 1821, and 1822 by John Franklin. Appendix 6. John Murray, London.

—— 1835. Salmones, p. 55–58. *In* J. C. Ross [ed.] Appendix to the narrative of a 2nd voyage in search of a north-west passage, and of a residence in the Arctic regions during the years 1829, 1830, 1831, 1832 and 1833. A. W. Webster, London.

—— 1836. Fauna Boreali-Americana; or the zoology of the northern parts of British America: part third *The fish*. Richard Bentley, London. 327 p.

—— 1854. Vertebrates, including fossil mammals. Fishes, p. 156–171. *In* E. Forbes [ed.] The zoology of the voyage of H.M.S. "Herald", under the command of Captain Henry Kellett, R.N., during the years 1845–51. London.

Richardson, J. H. 1908. *Salmo salar* in Ontario. Univ. Month. 8(3): 97–103.

Richardson, L. R. MS 1935. The fresh-water fishes of south-eastern Quebec. Ph.D. Thesis. Dep. Zool. McGill Univ., Montreal, Que. 196 p.

—— 1937. Observations on the mating and spawning of *Pimephales promelas* (Raf.). Can. Field-Natur. 51(1): 1–4.

—— 1938. A note on variation in squamation of the cheek operculum in two etheostomid fishes from Quebec. Copeia 1938(3): 126–128.

—— 1939. The spawning behavior of *Fundulus diaphanus* (LeSueur). Copeia 1939(3): 165–167.

—— 1944. Brief records of fishes from central Quebec. Copeia 1944(4): 205–208.

Richmond, N. D. 1940. Nesting of the sunfish, *Lepomis auritus* (Linnaeus), in tidal waters. Zoologica 25(3): 329–331.

Ricker, K. E. 1959. The origin of two glacial relict crustaceans in North America, as related to Pleistocene glaciation. Can. J. Zool. 37(6): 871–893.

Ricker, W. E. 1932. Studies of speckled trout (*Salvelinus fontinalis*) in Ontario. Univ. Toronto Stud. Biol. Ser. 36, Publ. Ont. Fish. Res. Lab. 44: 67–110.

—— 1933. Destruction of sockeye salmon by predatory fishes. Fish. Res. Board Canada Progr. Rep. Pac. 18: 3–4.

—— 1934. An ecological classification of certain Ontario streams. Univ. Toronto Stud. Biol. Ser. 37, Publ. Ont. Fish. Res. Lab. 49: 114 p.

—— 1938a. A comparison of the seasonal growth rates of young sockeye salmon and young squawfish in Cultus Lake. Fish. Res. Board Canada Progr. Rep. Pac. 36: 3–5.

—— 1938b. "Residual" and kokanee salmon in Cultus Lake. J. Fish. Res. Board Canada 4(3): 192–218.

—— 1940. On the origin of kokanee, a fresh-water type of sockeye salmon. Trans. Roy. Soc. Canada ser. 3, 34, sec. 5: 121–135.

—— 1941. The consumption of young sockeye salmon by predaceous fish. J. Fish. Res. Board Canada 5(3): 293–313.

—— 1959. Additional observations concerning residual sockeye and kokanee (*Oncorhynchus nerka*). J. Fish. Res. Board Canada 16(6): 897–902.

—— 1960. A population of dwarf coastrange sculpins (*Cottus aleuticus*). J. Fish. Res. Board Canada 17(6): 929–932.

—— 1966. Salmon of the North Pacific ocean — Part 3. A review of the life history of North Pacific salmon. 4. Sockeye salmon in British Columbia. Int. North Pac. Fish. Comm. Bull. 18: 59–70.

Riggs, C. D. 1955. Reproduction of the white bass, *Morone chrysops*. Invest. Indiana Lakes Streams 4(3): 87–110.

Rimsky-Korsakoff, V. N. 1930. The food of certain fishes of the Lake Champlain watershed, p. 88–104. *In* A biological survey of the Champlain watershed. Suppl. 19th Ann. Rep. N.Y. Conserv. Dep. 1929. 321 p.

Roach, L. S., and I. M. Evans. 1948. Growth of game and pan fish in Ohio. 2. Crappies. Ohio Div. Conserv. Sec. Fish Manage., Fish Manage. Rep. 29 p.

Robertson, J. G. 1949. Sockeye fry production in a small British Columbia coastal watershed. Fish. Res. Board Canada Prog. Rep. Pac. 80: 55–57.

Robins, C. R., and R. R. Miller. 1957. Classification, variation, and distribution of the sculpins, genus *Cottus*, inhabiting Pacific Slope waters in California and southern Oregon, with a key to the species. Calif. Fish Game 43(3): 213–233.

Robins, C. R., and E. C. Raney. 1956. Studies of the catostomid fishes of the genus *Moxostoma*, with descriptions of two new species. Mem. Agr. Exp. Sta. Ithaca 343: 56 p.

Ronald, K., and K. A. Wilson. MS 1968. A check list of the parasites of the order Petromyzontiformes (lampreys). Fish. Res. Board Canada Tech. Rep. 48: 23 p.

Roos, J. F. 1959. Feeding habits of the Dolly Varden, *Salvelinus malma* (Walbaum), at Chignik, Alaska. Trans. Amer. Fish. Soc. 88 (1959): 253–260.

—— 1960. Predation of young coho salmon on sockeye salmon fry at Chignik, Alaska. Trans. Amer. Fish. Soc. 89(4): 377–379.

Roosevelt, R. B. 1884. Superior fishing, or the striped bass, trout, black bass and blue-fish of the northern states. Embracing full directions for dressing artificial flies with the feathers of American birds, an account of a sporting visit to lake Superior, etc. 2nd ed. New York, N.Y.

Roseborough, J. D. 1962. Smelt harvest by sport fishermen in Lake Erie. Ont. Fish Wildlife Rev. 1(4): 8–12.

Rosen, D. E. 1964. The relationships and taxonomic position of the halfbeaks, killifishes, silversides, and their relatives. Bull. Amer. Mus. Natur. Hist. 127(5): 219–267.

Rostlund, E. 1952. Freshwater fish and fishing in native North America. Univ. Calif. Publ. Geogr. 9: 313 p.

Rothschild, B. J. 1966. Observations on the alewife (*Alosa pseudoharengus*) in Cayuga Lake. N.Y. Fish Game J. 13(2): 188–195.

Rounsefell, G. A. 1957. Fecundity of North American Salmonidae. U.S. Fish Wildlife Serv. Fish. Bull. 122, Vol. 57: 451–468.

—— 1958. Anadromy in North American Salmonidae. U.S. Fish Wildlife Serv. Fish. Bull. 131, Vol. 58: 171–185.

—— 1962. Relationships among North American Salmonidae. U.S. Fish Wildlife Serv. Fish. Bull. 209, Vol. 62: 235–270.

Rounsefell, G. A., and L. D. Stringer. 1943. Restoration and management of the New England alewife fisheries with special reference to Maine. U.S. Fish Wildlife Serv. Fish Leafl. 42: 33 p.

Roussow, G. 1955. Quelques observations sur les variation de forme et de couleur chez les esturgeons de la Province de Québec. Annales de l'Acfas 21: 79–85.

—— 1957. Some considerations concerning sturgeon spawning periodicity. J. Fish. Res. Board Canada 14(4): 553–572.

—— 1960. Cycle du parasite *Diphyllobothrium latum* (Linne). J. de bord de l'office biol. 3(52): 398–401.

Rowan, M. J. MS 1962. The effect of temperature on the young-of-the-year smallmouth black bass (*Micropterus dolomieu*). M.A. Thesis. Dep. Zool. Univ. Toronto, Toronto, Ont. 43 p.

Roy, J. M. 1969. The American shad and the alewife. Fishes of Quebec Album 8: 24 p.

Rupp, R. S. 1965. Shore-spawning and survival of eggs of the American smelt. Trans. Amer. Fish. Soc. 94(2): 160–168.

—— 1968. Life history and ecology of the smelt (*Osmerus mordax*) in inland waters of Maine. Maine Dep. Inland Fish Game. 36 p. (Mimeo.)

Rupp, R. S., and M. C. Meyer. 1954. Mortality among brook trout, *Salvelinus fontinalis*, resulting from attacks of freshwater leeches. Copeia 1954(4): 294–295.

Ryder, J. A. 1886. The development of *Fundulus heteroclitus*. Amer. Natur. 20: 824.

Ryder, R. A. 1961. Lymphocystis as a mortality factor in a walleye population. Progr. Fish-Cult. 23(4): 183–186.

—— 1968. Dynamics and exploitation of mature walleyes, *Stizostedion vitreum vitreum*, in the Nipigon Bay region of Lake Superior. J. Fish. Res. Board Canada 25(7): 1347–1376.

Ryder, R. A., W. B. Scott, and E. J. Crossman. 1964. Fishes of northern Ontario, north of the Albany River. Roy. Ont. Mus. Univ. Toronto, Life Sci. Div. Contrib. 60: 30 p.

Saksena, V. P., K. Yamamoto, and C. D. Riggs. 1961. Early development of the channel catfish. Prog. Fish-Cult. 23(4): 156–161.

Sale, P. F. 1967. A re-examination of the taxonomic position of the aurora trout. Can. J. Zool. 45(2): 215–225.

Sandeman, I. M., and J. H. C. Pippy. 1967. Parasites of freshwater fishes (Salmonidae and Coregonidae) of insular Newfoundland. J. Fish. Res. Board Canada 24(9): 1911–1943.

Sandercock, F. K. 1964. A contribution to the ecology of the whitefishes *Prosopium cylindraceum* and *Coregonus clupeaformis* of Algonquin Park, Ontario. Dep. Zool. Univ. British Columbia, Vancouver, B.C. 63 p. (Mimeo.)

Sato, Ryuhe. 1952. Biological observation on the pond smelt, *Hypomesus olidus* (Pallas), in Lake Kogawara, Aomori Prefecture, Japan. II. Early life history of the fish. Tohoku J. Agr. Res. 3(1): 175–184.

Saunders, L. H., and J. A. McKenzie. 1971. Comparative electrophoresis of arctic char. Comp. Biochem. Physiol. 38B: 487–492.

Saunders, L. H., and G. Power. 1969. The Arctic char, *Salvelinus alpinus* (Linnaeus), of Matamek Lake, Quebec. Natur. Can. 96: 919–934.

Savage, J. 1933. *Imostoma shumardi* in northwestern Ontario. Copeia 1933(1): 34.

Savage, T. 1962. *Cottus girardi* Robins, a synonym of *Cottus bairdi* Girard. Copeia 1962(4): 848–850.

—— 1963. Reproductive behavior of the mottled sculpin, *Cottus bairdi* Girard. Copeia 1963(2): 317–325.

Schaner, E., and K. Sherman. 1960. Observations on the fecundity of the tomcod, *Microgadus tomcod* (Walbaum). Copeia 1960(4): 347–348.

Schmidt, G. D. 1969. *Paracanthocephalus rauschi* sp. n. (Acanthocephala: Paracanthocephalidae) from grayling, *Thymallus arcticus* (Pallas), in Alaska. Can. J. Zool. 47(3): 383–385.

Schmidt, J. 1922. The breeding places of the eel. Phil. Trans. Roy. Soc. London, ser. B, vol. 211: 179–208.

Schneberger, E. 1937. The biological and economic importance of the smelt in Green Bay. Trans. Amer. Fish. Soc. 66 (1936): 139–142.

Schultz, F. H. 1955. Investigation of the spawning of northern pike in Prince Albert National Park, Saskatchewan, 1953. Can. Wildlife Serv. Wildlife Manage. Bull. 3(4): 21 p.

Schultz, L. P. 1926. Temperature-controlled variation in the golden shiner, *Notemigonus crysoleucas*. Pap. Mich. Acad. Sci. Arts Lett. 7: 417–432 + 1 pl.

—— 1929. Description of a new type of mudminnow from western Washington with notes on related species. Coll. Fish. Univ. Washington Publ. Fish. 2(6): 73–81.

—— 1930. The life history of *Lampetra planeri* Bloch with a statistical analysis of the rate of growth of the larvae from western Washington. Occas. Pap. Mus. Zool. Univ. Mich. 221: 35 p. + 2 pls.

—— 1935. The spawning habits of the chub, *Mylocheilus caurinus* — a forage fish of some value. Trans. Amer. Fish. Soc. 65 (1935): 143–147.

—— 1941. Fishes of Glacier National Park, Montana. U.S. Dept. Int., Nat. Park Serv. Conserv. Bull. 22: 42 p. + 26 figs.

Schultz, L. P., and W. M. Chapman. 1934. A new osmerid fish, *Spirinchus dilatus*, from Puget Sound. Ann. Mag. Natur. Hist. ser. 10, vol. 13: 67–78 + figs.

Schultz, L. P., and W. A. Spoor. 1933. *Cottus protrusus*, a new sculpin from Unalaska Island. Copeia 1933(3): 142–145.

Schultz, L. P., and students. 1935. The breeding activities of the little redfish, a landlocked form of the sockeye salmon *Oncorhynchus nerka*. J. Pan-Pac. Res. Inst. 10(1): 67–77.

Schwartz, F. J. 1956. First record of infestation and death in the ictalurid catfish, *Schilbeodes miurus*, by the parasite *Clinostomum marginatum*. Copeia 1956(4): 250–251.

—— 1965. Age, growth and egg complement of the stickleback *Apeltes quadracus* at Solomons, Maryland.
—— 1963. The fresh-water minnows of Maryland. Md. Conserv. 40(2): 19–29.
Chesapeake Sci. 6(2): 116–118.

Schwartz, F. J., and J. Norvell. 1958. Food, growth and sexual dimorphism of the redside dace *Clinostomus elongatus* (Kirtland) in Linesville Creek, Crawford County, Pennsylvania. Ohio J. Sci. 58(5): 311–316.

Scofield, N. B. 1899. List of fishes obtained in waters of Arctic Alaska, p. 493–509. *In* D. S. Jordan [ed.] The fur-seals and fur-seal islands of the North Pacific Ocean. Rep. of the fur-seal investigations 1896–1897. Part 3. Washington, D.C.

Scofield, N. B., and G. A. Coleman. 1910. Notes on spawning and hatching striped bass eggs at Bouldin Island hatchery. Rep. Board Fish Game Comm. Calif. (1907–1908), App. to Rep 1909–1910. p. 109–117 + 3 pls.

Scott, D. C. 1955. Activity patterns of perch, *Perca flavescens*, in Rondeau Bay of Lake Erie. Ecology 36(2): 320–327.

Scott, D. M. 1955. Additional records of two fishes, *Erimyzon sucetta kennerlyi* and *Hadropterus copelandi*, from southern Ontario, Canada. Copeia 1955(2): 151.

Scott, D. P. 1962. Effect of food quantity on fecundity of rainbow trout, *Salmo gairdneri*. J. Fish. Res. Board Canada 19(4): 715–730.

Scott, Will. 1938. The food of *Amia* and *Lepistosteus*. Invest. Indiana Lakes Streams, art. 9: 112–115.

Scott, W. B. MS 1950. The Lake Erie cisco (*Leucichthys artedi*) population. Ph.D. Thesis. Univ. Toronto, Toronto, Ont. 112 p. + 29 tables.

—— 1951. Fluctuations in abundance of the Lake Erie cisco (*Leucichthys artedi*) population. Contrib. Roy. Ont. Mus. Zool. 32: 41 p.

—— 1952. Records of the western lake chubsucker, *Erimyzon sucetta kennerleyi*, from Ontario, Canada. Copeia 1952(3): 203.

—— 1954. Freshwater fishes of eastern Canada. Univ. Toronto Press, Toronto, Ont. 128 p.

—— 1956. Wendigo — the hybrid trout. Roy. Ont. Mus. Div. Zool. Palaeontol. 7 p.

—— 1957a. Distributional records of fishes in western Canada. Copeia 1957(2): 160–161.

—— 1957b. Changes in the fish fauna of Ontario, p. 19–25. *In* F. A. Urquhart [ed.] Changes in the fauna of Ontario. Univ. Toronto Press, Toronto, Ont. 75 p.

—— 1958. A checklist of the freshwater fishes of Canada and Alaska. Roy. Ont. Mus. Zool. Palaeontol. 30 p.

—— 1963. A review of the changes in the fish fauna of Ontario. Trans. Roy. Can. Inst. 34(2): 111–125.

—— 1967. Freshwater fishes of eastern Canada. 2nd ed. Univ. Toronto Press, Toronto, Ont. 137 p.

Scott, W. B., and W. J. Christie. 1963. The invasion of the lower Great Lakes by the white perch, *Roccus americanus* (Gmelin). J. Fish. Res. Board Canada 20(5): 1189–1195.

Scott, W. B., and E. J. Crossman. 1959. The freshwater fishes of New Brunswick: a checklist with distributional notes. Contrib. Roy. Ont. Mus. Div. Zool. Palaeont. 51: 37 p.

—— 1964. Fishes occurring in the fresh waters of insular Newfoundland. Dep. Fish. Ottawa. 124 p.

—— 1967. Provisional checklist of Canadian freshwater fishes. Inform. Leafl. Dept. Ichthy. Herpetol. Roy. Ont. Mus. July. 24 p.

—— 1969. Checklist of Canadian freshwater fishes with keys for identification. Life Sci. Misc. Publ. Roy. Ont. Mus. 104 p.

Scott, W. B., and B. Kooyman. 1952. A northern record for *Aplodinotus grunniens*. Can. Field-Natur. 66(3): 89.

Scott, W. B., and S. H. Smith. 1962. The occurrence of the longjaw cisco, *Leucichthys alpenae*, in Lake Erie. J. Fish. Res. Board Canada 19(6): 1013–1023.

Seabrook, W. D. 1961. A preliminary report on the biology of the non-migratory char of Butts Pond. Progr. Rep. Fish Cult. Dep., Dep. Fish. St. John's, Nfld. 37 p.

Seal, W. P. 1932. Breeding habits of the four-spined stickleback (*Apeltes quadracus*). Aquarium, Philadelphia 1(2): 38–41.

Séguin, L.-R. 1955. Moeurs et méthodes d'élevage des truites du Québec. Le Jeune Natur. 5(7): 146–176.

Self, J. T. 1954. Parasites of the goldeye, *Hiodon alosoides* (Raf.), in Lake Texoma. J. Parasitol. 40(4): 386–389.

Semakula, S. N. MS 1963. The age and growth of the white sturgeon (*Acipenser transmontanus* Richardson) of the Fraser River, British Columbia, Canada. M.Sc. Thesis. Dep. Zool. Univ. British Columbia, Vancouver, B.C. 115 p.

Semakula, S. N., and P. A. Larkin. 1968. Age, growth, food, and yield of the white sturgeon (*Acipenser transmontanus*) of the Fraser River, British Columbia. J. Fish. Res. Board Canada 25(12): 2589–2602.

Shaposhnikova, G. Kh. 1967. Sravnitelnaya kharakteristika nelmy *Stenodus leucichthys nelma* (Pallas) i belorybitsy *Stenodus leucichthys leucichthys* (Güldenstadt). (Comparative characteristics of *Stenodus leucichthys nelma* (Pallas) and "Caspian inconnu" (Güldenstadt).) Vopr. Ikhtiol. 7: 227–239.

Shapovalov, L., and A. C. Taft. 1954. The life histories of the steelhead rainbow trout (*Salmo gairdneri gairdneri*) and silver salmon (*Oncorhynchus kisutch*) with special reference to Waddell Creek, California, and recommendations regarding their management. Calif. Dep. Fish Game Bull. 98: 375 p.

Shepard, M. P. 1955. Resistance and tolerance of young speckled trout (*Salvelinus fontinalis*) to oxygen lack, with special reference to low oxygen acclimation. J. Fish. Res. Board Canada 12(3): 387–446.

Sheri, A. N., and G. Power. 1968. Reproduction of white perch, *Roccus americanus*, in the Bay of Quinte, Lake Ontario. J. Fish. Res. Board Canada 25(10): 2225–2231.

—— 1969a. Annulus formation on scales of the white perch, *Morone americanus* (Gmelin), in the Bay of Quinte, Lake Ontario. Trans. Amer. Fish. Soc. 98(2): 322–326.

—— 1969b. Vertical distribution of white perch, *Roccus americanus*, modified by light. Can. Field-Natur. 83(2): 160–161.

—— 1969c. Fecundity of the yellow perch, *Perca flavescens* Mitchill, in the Bay of Quinte, Lake Ontario. Can. J. Zool. 47(1): 55–58.

SHETTER, D. S., and G. R. ALEXANDER. 1965. Results of angling under special and normal trout fishing regulations in a Michigan trout stream. Trans. Amer. Fish. Soc. 94(3): 219–226.

—— 1970. Results of predator reduction on brook trout and brown trout in 4.2 miles (6.76 km) of the north branch of the Au Sable River. Trans. Amer. Fish. Soc. 99(2): 312–319.

SHIELDS, J. T. 1957. Experimental control of carp reproduction through water drawdowns in Fort Randall Reservoir, South Dakota. Trans. Amer. Fish. Soc. 87 (1957): 23–38.

SHOEMAKER, H. H. 1947. Pickerel and pumpkinseed coaction over the sunfish nest. Copeia 1947(3): 195–196.

SHUFELDT, R. W. 1900. The skeleton of the black bass. U.S. Fish Comm. Bull. (1899) 19: 311–320 + 1 pl.

SIBLEY, C. K., and V. M. RIMSKY-KORSAKOFF. 1931. Food of certain fishes in the watershed, p. 109–120. *In* A biological survey of the St. Lawrence watershed. Suppl. 20th Ann. Rep. N.Y. State Conserv. Dep. 1930. 261 p.

SIEFERT, R. E. 1968. Reproductive behavior, incubation and mortality of eggs, and postlarval food selection in the white crappie. Trans. Amer. Fish. Soc. 97(3): 252–259.

—— 1969. Characteristics for separation of white and black crappie larvae. Trans. Amer. Fish. Soc. 98(2): 326–328.

SIGLER, W. F. 1958. The ecology and use of carp in Utah. Utah State Univ. Logan Agric. Exp. Sta. Bull. 405: 63 p.

SIGLER, W. F., and R. R. MILLER. 1963. Fishes of Utah. Utah State Dep. Fish Game, Salt Lake City, Utah. 203 p.

SIMON, J. R. 1946. Wyoming fishes. Wyoming Game Fish Dep. Bull. 4: 129 p.

SIMON, R. C., and A. M. DOLLAR. 1963. Cytological aspects of speciation in two North American teleosts, *Salmo gairdneri* and *Salmo clarki lewisi*. Can. J. Genet. Cytol. 5(1): 43–49.

SIMON, R. C., and R. E. NOBLE. 1968. Hybridization in *Oncorhynchus* (Salmonidae). I. Viability and inheritance in artificial crosses of chum and pink salmon. Trans. Amer. Fish. Soc. 97(2): 109–118.

SINCLAIR, S., S. TRACHTENBERG, and M. L. BECKFORD. 1967. Physical and economic organization of the fisheries of the District of Mackenzie, Northwest Territories. Fish. Res. Board Canada Bull. 158: 70 p.

SKUD, B. E. 1955. Length–weight relationship in migrating fry of pink salmon (*Oncorhynchus gorbuscha*) in Sashin Creek, Little Port Walter, Alaska. Copeia 1955(3): 204–207.

SLASTENENKO, E. P. 1958. The freshwater fishes of Canada. Kiev Printers, Toronto, Ont. 383 p.

SMALL, H. B. 1865. The animals of North America. ser. 2. Fresh-water fish. M. Longmoore & Co., Montreal, Que. p. 1–72.

—— 1883. Fishes of the Ottawa district. Trans. Ottawa Field Natur. Club 4, 1882–1885: 31–49.

SMALLWOOD, W. M., and M. L. SMALLWOOD. 1929. The German carp, an invited immigrant. Sci. Month. 29: 394–401.

SMEDLEY, E. M. 1933. Nematode parasites from Canadian marine and fresh water fishes. Contrib. Can. Biol. Fish. n.s. 8(14): 169–179.

SMITH, G. R. 1966. Distribution and evolution of the North American catostomid fishes of the subgenus *Pantosteus*, genus *Catostomus*. Misc. Publ. Mus. Zool. Univ. Mich. 129: 132 p. + 1 pl.

SMITH, H. M. 1892. Report on the investigation of the fisheries of Lake Ontario. Bull. U.S. Fish Comm. 1890, 10: 177–215.

—— 1895. Notes on two hitherto unrecognized species of American whitefishes. Bull. U.S. Fish Comm. 1894, 14: 1–13.

—— 1907. The fishes of North Carolina. N.C. Geol. Econ. Surv. 2: 453 p.

SMITH, L. L., JR., and R. H. KRAMER. 1964. The spottail shiner in Lower Red Lake, Minnesota. Trans. Amer. Fish. Soc. 93(1): 35–45.

SMITH, M. W. 1938. A preliminary account of the fish population in certain Nova Scotian lakes. Trans. Amer. Fish. Soc. 67 (1937): 178–183.

—— 1939. The fish population of Lake Jesse, Nova Scotia. Proc. Nova Scotian Inst. Sci. (for 1937–38) 19(4): 389–427.

—— 1942. The smallmouth black bass in the Maritime provinces. Fish. Res. Board Canada Progr. Rep. Atl. 32: 3–4.

—— 1947. Food of killifish and white perch in relation to supply. J. Fish. Res. Board Canada 7(1): 22–34.

—— 1952. Limnology and trout angling in Charlotte County lakes, New Brunswick. J. Fish. Res. Board Canada 8(6): 383–452.

SMITH, M. W., and J. W. SAUNDERS. 1955. The American eel in certain fresh waters of the Maritime Provinces of Canada. J. Fish. Res. Board Canada 12(2): 238–269.

—— 1958. Movements of brook trout, *Salvelinus fontinalis* (Mitchill), between and within fresh and salt water. J. Fish. Res. Board Canada 15(6): 1403–1449.

—— 1967. Movements of brook trout in relation to an artificial pond on a small stream. J. Fish. Res. Board Canada 24(8): 1743–1761.

Smith, O. R. 1941. The spawning habits of cutthroat and eastern brook trouts. J. Wildlife Manage. 5(4): 461–471.

Smith, Rosa. 1882. Description of a new species of *Uranidea* (*U. rhothea*) from Spokane river, Washington territory. Proc. U.S. Nat. Mus. 5: 347–348.

Smith, R. F. 1949. Notes on *Ergasilus* parasites from the New Brunswick, New Jersey, area, with a check list of all species and hosts east of the Mississippi River. Zoologica 34(15): 127–133.

Smith, S. B. 1955. The relation between scale diameter and body length of Kamloops trout, *Salmo gairdneri kamloops*. J. Fish. Res. Board Canada 12(5): 742–753.

Smith, S. H. 1956. Life history of lake herring of Green Bay, Lake Michigan. U.S. Fish Wildlife Serv. Fish. Bull. 109, Vol. 57: 87–138.

—— 1964a. Status of the deepwater cisco population of Lake Michigan. Trans. Amer. Fish. Soc. 93(2): 155–163.

—— 1964b. The taxonomic status of *Leucichthys macropterus*, a cisco of Lake Erie. Copeia 1964(1): 230.

—— 1968. Species succession and fishery exploitation in the Great Lakes. J. Fish. Res. Board Canada 25(4): 667–693.

Smitt, F. A. 1893–1895. A history of Scandinavian fishes. Stockholm and London. 2 pts. 566 p.

Sneed, K. E. 1951. A method for calculating the growth of channel catfish, *Ictalurus lacustris punctatus*. Trans. Amer. Fish. Soc. 80 (1950): 174–183.

—— 1964. Southeastern Fish Cultural Laboratory. U.S. Fish Wildlife Serv. Circ. 178: 111–118.

Snieszko, S. F. 1952. Ulcer disease in brook trout (*Salvelinus fontinalis*): its economic importance, diagnosis, treatment, and prevention. Progr. Fish-Cult. 14(2): 43–49.

Snow, H. E. 1969. Comparative growth of eight species of fish in thirteen northern Wisconsin lakes. Res. Rep. Dep. Natur. Res. Madison, Wis. 46: 23 p.

Snyder, J. O. 1917. Coulter's whitefish. Copeia 1917(50): 93–94.

Spangler, G. R. 1968. Angler harvest and mortality of *Esox masquinongy* in Pigeon and Sturgeon lakes, Ontario. J. Fish. Res. Board Canada 25(6): 1145–1154.

Sparrow, R. A. H. 1968. A first report of chum salmon fry feeding in fresh water of British Columbia. J. Fish. Res. Board Canada 25(3): 599–602.

Speirs, J. M. 1951. History of the original descriptions of Great Lakes fishes. Paper presented at R.C.O. Technical Session, London, Ont., Feb. 24, 1951. 38 p.

—— 1952. Nomenclature of the channel catfish and the burbot of North America. Copeia 1952(2): 99–103.

Spoor, W. A. 1935. On the sexual dimorphism of *Catostomus commersonii* (Lacépède). Copeia 1935(4): 167–171.

Sprules, W. M. 1952. The Arctic char of the west coast of Hudson Bay. J. Fish. Res. Board Canada 9(1): 1–15.

Sprules, W. M., and K. H. Doan. 1947. Records of the mooneye (*Hiodon tergisus*) and the quillback sucker (*Carpiodes cyprinus*) from Saskatchewan. Copeia 1947(3): 196–197.

Stafford, J. 1907. Preliminary report on the trematodes of Canadian marine fishes. Contrib. Can. Biol. 1902–1905, Sess. Pap. 22a: 91–94.

Starks, E. C. 1904. A synopsis of characters of some fishes belonging to the order Haplomi. Biol. Bull. (Woods Hole) 7: 254–262.

Starrett, W. C. 1951. Some factors affecting the abundance of minnows in the Des Moines River, Iowa. Ecology 32(1): 13–27.

Steindachner, F. 1870. Ichthyologische Notizen. Sitzber. Akad. Wiss. Wien. 61: 1–26; 429.

Stenton, J. E. 1950. Artificial hybridization of eastern brook trout and lake trout. Can. Fish Cult. 6: 2–4.

—— 1951. Eastern brook trout eggs taken by longnose suckers in Banff National Park, Canada. Copeia 1951(2): 171–173.

—— 1952. Additional information on eastern brook trout × lake trout hybrids. Can. Fish Cult. 13: 1–7.

Sterba, G. 1962. Freshwater fishes of the world. Vista Books, London. 878 p.

Stewart, K. 1964. Million dollar fish from Manitoba. Can. Dep. Fish. Trade News 17(2): 5–6.

Stewart, K. W., and C. C. Lindsey. 1970. First specimens of the stonecat, *Noturus flavus*, from the Hudson Bay drainage. J. Fish. Res. Board Canada 27(1): 170–172.

Stewart, N. H. 1926. Development, growth, and food habits of the white sucker, *Catostomus commersonii* LeSueur. Bull. Bur. Fish. 42, doc. 1007: 147–184.

Stewart-Hay, R. K. 1954. A killifish in Manitoba. Can. Field-Natur. 68(2): 94.

Stockard, C. R. 1909. The influence of alcohol and other anesthetics on developing embryos. Proc. Soc. Exp. Biol. Med. N.Y. 7: 1–2.

—— 1910. The influence of alcohol and other anaesthetics on embryonic development. Amer. J. Anat. 10: 369–392.

STONE, F. L. 1947. Notes on two darters of the genus *Boleosoma*. Copeia 1947(2): 92–96.

—— MS 1948. A study of the taxonomy of the blue and the yellow pikeperches (*Stizostedion*) of Lake Erie and Lake Ontario. Ph.D. Thesis. Dep. Zool. Univ. Rochester, Rochester, N.Y. 164 p.

STONE, U. B. 1938. Growth, habits, and fecundity of the ciscoes of Irondequoit Bay, New York. Trans. Amer. Fish. Soc. 67 (1937): 234–245.

—— 1941. Studies on the biology of the satinfin minnows, *Notropis analostanus* and *Notropis spilopterus*. Cornell Univ. Abstr. Theses 1940. p. 288–290.

—— 1947. A study of the deep-water cisco fishery of Lake Ontario with particular reference to the bloater, *Leucichthys hoyi* (Gill). Trans. Amer. Fish. Soc. 74 (1944): 230–249.

STORER, D. H. 1845. Description of hitherto undescribed fishes. Proc. Boston Soc. Natur. Hist. 2: 47–49.

—— 1846. A synopsis of the fishes of North America. Memoirs Amer. Acad. Arts Sci. 2 (1930): 253–550.

STORER, H. R. 1857. Observations on the fishes of Nova Scotia and Labrador, with descriptions of new species. Boston J. Natur. Hist. 1850–1857, 6: 247–270.

STRAWN, K. 1958. Optimum and extreme temperatures for growth and survival: various fishes. Data for Handb. Biol. Data. 1 p.

STROUD, R. H. 1948. Notes on growth of hybrids between the sauger and the walleye (*Stizostedion canadense canadense* × *S. vitreum vitreum*) in Norris Reservoir, Tennessee. Copeia 1948(4): 297–298.

—— 1955. Fisheries report for some central, eastern, and western Massachusetts lakes, ponds, and reservoirs, 1951–52. Dep. Conserv. Div. Fish Game. 447 p.

SUCKLEY, G. 1860. Report upon the fishes collected on the survey, No. 5. Chapter 1. Report upon the Salmonidae, p. 307–349. *In* Reports of explorations and surveys to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean, made under the direction of the Secretary of War, in 1853–1855, according to act of Congress, of March 3, 1853, May 31, 1854, and August 5, 1854. Vol. 12, book 2. 36th Congress. 1st session, Senate Exec. Doc. Washington.

—— 1862a. Description of several new species of Salmonidae from the north-west coast of America. Ann. Lyceum Natur. Hist. N.Y. 7: 1–10.

—— 1862b. Notices of certain new species of North American Salmonidae, chiefly in the collection of the North-west Boundary Commission. Ann. Lyceum Natur. Hist. N.Y. 7: 306–313.

—— 1874. On the North American species of salmon and trout. Appendix B. Part 3, p. 91–160. *In* Report of the Commissioner for 1872–1873. U.S. Comm. Fish Fish.

SUMMERFELT, R. C. 1964. A new microsporidian parasite from the golden shiner, *Notemigonus crysoleucas*. Trans. Amer. Fish. Soc. 93(1): 6–10.

SUMMERFELT, R. C., and C. O. MINCKLEY. 1969. Aspects of the life history of the sand shiner, *Notropis stramineus* (Cope), in the Smoky Hill River, Kansas. Trans. Amer. Fish. Soc. 98(3): 444–453.

SUMNER, F. B., R. C. OSBURN, and L. J. COLE. 1913. A biological survey of the waters of Woods Hole and vicinity. Part 2, Sect. 3. A catalogue of the marine fauna. Bull. Bur. Fish. 31, 1911: 549–794.

SUTTKUS, R. D. 1958. Status of the nominal cyprinid species *Moniana deliciosa* Girard and *Cyprinella texana* Girard. Copeia 1958(4): 307–318.

—— 1963. Order Lepisostei, p. 61–88. *In* Fishes of the western North Atlantic. Mem. Sears Found. Mar. Res. 1(3): 630 p.

SVARDSON, G. 1957. The coregonid problem. VI. The Palearctic species and their intergrades. Rep. Inst. Freshwater Res. Drottningholm 38: 261–356.

SVETOVIDOV, A. N., and E. A. DOROFEEVA. 1963. Systematics, origin, and history of the distribution of the Eurasian and North American perches and pike-perches (genera *Perca*, *Lucioperca*, and *Stizostedion*). Vop. Ikhtiol. 3(4): 625–651. (English translation Bur. Comm. Fish. Washington.)

SWAN, J. G. 1881. The eulachon or candle-fish of the northwest coast. Proc. U.S. Nat. Mus. (1880) 3: 257–264.

SWEE, U. B., and H. R. MCCRIMMON. 1966. Reproductive biology of the carp, *Cyprinus carpio* L., in Lake St. Lawrence, Ontario. Trans. Amer. Fish. Soc. 95(4): 372–380.

TAIT, J. S. 1970. A method of selecting trout hybrids (*Salvelinus fontinalis* × *S. namaycush*) for ability to retain swimbladder gas. J. Fish. Res. Board Canada 27(1): 39–45.

TAMBS-LYCHE, H. 1963. Norwegian Petromyzontidae. Sarsia 11: 21–24.

TAYLOR, W. R. 1954. Records of fishes in the John N. Lowe collection from the Upper Peninsula of Michigan. Misc. Publ. Mus. Zool. Univ. Mich. 87: 50 p.

—— MS 1955. A revision of the genus *Noturus* Rafinesque with a contribution to the classification of the North American catfishes. Ph.D. Thesis. Univ. Michigan, Ann Arbor, Mich. 583 p.

—— 1969. A revision of the catfish genus *Noturus* Rafinesque with an analysis of higher groups in the Ictaluridae. U.S. Nat. Mus. Bull. 282: 315 p.

TCHERNAVIN, V. 1943. The breeding characters of salmon in relation to their size. Proc. Zool. Soc. ser. B., 113: 206–232.

TEDLA, S., and C. H. FERNANDO. 1969a. Observations on the seasonal changes of the parasite fauna of yellow perch (*Perca flavescens*) from the Bay of Quinte, Lake Ontario. J. Fish. Res. Board Canada 26(4): 833–843.

—— 1969b. Observations on the glochidia of *Lampsilis radiata* (Gmelin) infesting yellow perch, *Perca flavescens* (Mitchill) in the Bay of Quinte, Lake Ontario. Can. J. Zool. 47(4): 705–712.

—— 1969c. Observations on the biology of *Ergasilus* spp. (Cyclopoidea: Copepoda) infesting North American freshwater fishes. Can. J. Zool. 47(3): 405–408.

—— 1970. Some aspects of the ecology of the parasite fauna of the gills of yellow perch, *Perca flavescens*. J. Fish. Res. Board Canada 27(6): 1045–1050.

Templeman, W., H. J. Squires, and A. M. Fleming. 1957. Nematodes in the fillets of cod and other fishes in Newfoundland and neighbouring areas. J. Fish. Res. Board Canada 14(6): 831–897.

Tester, A. L. 1930. Spawning habits of the small-mouthed black bass in Ontario waters. Trans. Amer. Fish. Soc. 60 (1930): 53–61.

—— 1932a. Food of the small-mouthed black bass (*Micropterus dolomieu*) in some Ontario waters. Univ. Toronto Stud. Biol. Ser. 36, Publ. Ont. Fish. Res. Lab. 46: 171–203.

—— 1932b. Rate of growth of the small-mouthed black bass (*Micropterus dolomieu*) in some Ontario waters. Univ. Toronto Stud., Publ. Ont. Fish. Res. Lab. 47: 205–221.

Tharratt, R. C. 1959. Food of yellow perch, *Perca flavescens* (Mitchill) in Saginaw Bay, Lake Huron. Trans. Amer. Fish. Soc. 88(4): 330–331.

Thoits, C. F. III. 1958. A compendium of the life history and ecology of the white perch *Morone americana* (Gmelin). Mass. Div. Fish. Game, Fish. Bull. 24: 1–16 + biblio. (Mimeo.)

Thomas, B. O. 1962. Behavioral studies of the brook stickleback, *Eucalia inconstans* (Kirtland). Amer. Zool. 2(3): 452.

Thomas, M. L. H. 1961. Lamprey fisheries, past and present, of North America and Europe. Fish. Res. Board Canada, Gen. Ser. Biol. Sta. London Circ. 3: 4–7.

Thompson, E. S. 1898. A list of the fishes known to occur in Manitoba. Forest and Stream 51(11): 214.

Thompson, R. B. 1959. Food of the squawfish *Ptychocheilus oregonensis* (Richardson) of the lower Columbia River. U.S. Fish Wildlife Serv. Fish Bull. 158, Vol. 60: 43–58.

Thompson, Zadock. 1842. History of Vermont, natural, civil, and statistical. 3 pts. Burlington, Vt.

—— 1850. No title. Proc. Boston Soc. Natur. Hist. 3: 305–306.

—— 1853. History of Vermont, natural, civil and statistical. 2nd ed. Appendix p. 33. Burlington, Vt.

Threinen, C. W., C. Wistrom, B. Apelgren, and H. Snow. 1966. The northern pike, its life history, ecology, and management. Wis. Conserv. Dep. Publ. 235: 16 p.

Threlfall, W., and G. Hanek. 1970. Metazoan parasites of salmonids and coregonids from the Avalon Peninsula, Newfoundland. J. Fish. Res. Board Canada 27(10): 1894–1897.

Tiffany, L. H. 1921. The gizzard shad in relation to plants and game fishes. Trans. Amer. Fish. Soc. 50 (1920): 381–386.

Todd, J. H., J. Atema, and J. E. Bardach. 1967. Chemical communication in social behavior of a fish, the yellow bullhead (*Ictalurus natalis*). Science 158(3801): 672–673.

Tody, W. H., and H. A. Tanner. 1966. Coho salmon for the Great Lakes. Mich. Dep. Conserv. Fish Manage Rep. 1: 38 p.

Toner, E. D. 1959. Predation by pike (*Esox lucius* L.) in three Irish lakes. Rep. Sea Inld. Fish. Eire, 1959: 67–73.

—— 1966. Synopsis of biological data on the pike *Esox lucius* Linnaeus 1758. FAO (Food Agr. Organ. U.N.) Fish. Synopsis 30. 36 p. + 5 fig. (Mimeo.)

Toner, G. C. 1933. Annotated list of fishes of Georgian Bay. Copeia 1933(3): 133–140.

—— 1934. Notes on the alewife. Can. Field-Natur. 48(3): 51–52.

—— 1937. Preliminary studies of the fishes of eastern Ontario. Bull. East. Ont. Fish Game Prot. Assoc., Supp. 2: 1–24.

—— 1938. Biological survey of lower Beverly Lake, Leeds County, Ontario. Bull. East. Ont. Fish Game Prot. Assoc., Supp. 3: 1–16.

—— MS 1943. Ecological and geographical distribution of fishes in eastern Ontario. M.A. Thesis. Univ. Toronto, Toronto, Ont. 91 p.

Trautman, M. B. 1931. *Notropis volucellus wickliffi*, a new subspecies of cyprinid fish from the Ohio and Upper Mississippi rivers. Ohio J. Sci. 31(6): 468–474.

—— 1948. A natural hybrid catfish, *Schilbeodes miurus* × *Schilbeodes mollis*. Copeia 1948(3): 166–174.

—— 1957. The fishes of Ohio with illustrated keys. Ohio State Univ. Press, Columbus, Ohio. 683 p.

Traver, J. R. 1929. The habits of the black-nosed dace, *Rhinichthys atronasus* Mitchill. J. Elisha Mitchell Sci. Soc. 45 (1929–1930): 101–129.

Trembley, F. J. 1930. The gar-pike of Lake Champlain, p. 139–145. *In* A Biological survey of the Champlain watershed. Suppl. 19th Ann. Rep. N.Y. Conserv. Dep. 1928. 321 p.

—— 1960. Research project on effect of condenser discharge water on aquatic life. Inst. Res. Lehigh Univ. Progr. Rep. 1956–1959.

Trent, L., and W. W. Hassler. 1966. Feeding behaviour of adult striped bass, *Roccus saxatilis*, in relation to stages of sexual maturity. Chesapeake Sci. 7(4): 189–192.

Tsuyuki, H., and E. Roberts. 1966. Inter-species relationships within the genus *Oncorhynchus* based on biochemical systematics. J. Fish. Res. Board Canada 23(1): 101–107.

Tucker, D. W. 1959. A new solution to the Atlantic eel problem. Nature 183: 495–501.

Tuomi, A. L. W. 1964. Statistics on salmon sport fishing in the tidal waters of British Columbia. Dep. Fish. Canada, Pac. 26 p.

Turner, C. L. 1921. Food of the common Ohio darters. Ohio J. Sci. 22(2): 41–62.

Turner, C. L., and W. C. Kraatz. 1921. Food of young large-mouth black bass in some Ohio waters. Trans. Amer. Fish. Soc. 50 (1920): 372–380.

Turner, G. E., and H. R. MacCrimmon. 1970. Reproduction and growth of smallmouth bass, *Micropterus dolomieui*, in a Precambrian lake. J. Fish. Res. Board Canada 27(2): 395–400.

Turner, L. M. 1886. Fishes, p. 87–113. *In* Contributions to the natural history of Alaska. Conducted under the auspices of the Signal Service, U.S.A., extending from May, 1874 to August, 1881. Govt. Printing Off., Washington. Arctic Series on publ. 2(4).

Tyler, A. V. 1966. Some lethal temperature relations of two minnows of the genus *Chrosomus*. Can. J. Zool. 44(3): 349–364.

Ulrey, L., C. Risk, and W. Scott. 1938. The number of eggs produced by some of our common fresh-water fishes. Invest. Indiana Lakes Streams 1(6): 73–77.

Underhill, J. C. 1957. The distribution of Minnesota minnows and darters in relation to Pleistocene glaciation. Occas. Pap. Minn. Mus. Natur. Hist. 7: 45 p.

—— 1963. Distribution in Minnesota of the subspecies of the percid fish *Etheostoma nigrum*, and of their intergrades. Amer. Midland Natur. 70(2): 470–478.

Ure, G. P. 1858. Fishes, p. 62–63. *In* The handbook of Toronto, by a member of the press. Toronto, Ont.

Uthe, J. F., and R. A. Ryder. 1970. Regional variation in muscle myogen polymorphism in walleye (*Stizostedion vitreum vitreum*) as related to morphology. J. Fish. Res. Board Canada 27(5): 923–927.

Van Bergeijk, W. A., and S. Alexander. 1962. Lateral line canal organs on the head of *Fundulus heteroclitus*. J. Morphol. 110(3): 333–346.

Van Cleave, H. J. 1921. Acanthocephala from the eel. Trans. Amer. Microsc. Soc. 40(1): 1–13.

—— 1923. Acanthocephala from the fishes of Oneida Lake, New York. Roosevelt Wild Life Bull. 2(1): 73–84.

Van Cleave, H. J., and J. F. Mueller. 1934. Parasites of Oneida Lake fishes. Pt. 3. A biological and ecological survey of the worm parasites. Bull. N.Y. State Coll. Forestry 7(1). Roosevelt Wild Life Annals 3(3): 161–334.

Vandermeer, J. H. 1966. Statistical analysis of geographic variation of the fathead minnow, *Pimephales promelas*. Copeia 1966(3): 457–466.

Van Duzer, E. M. 1939. Observations on the breeding habits of the cutlips minnow, *Exoglossum maxillingua*. Copeia 1939(2): 65–75.

Vanicek, D. 1961. Life history of the quillback and highfin carp suckers in the Des Moines River. Proc. Iowa Acad. Sci. 68: 238–246.

Van Oosten, J. 1929. Life history of the lake herring (*Leucichthys artedi* Le Sueur) of Lake Huron as revealed by its scales, with a critique of the scale method. Bull. Bur. Fish. 44, doc. 1053, (1928): 265–428.

—— 1935. First record of the alewife, *Pomolobus pseudo-harengus*, for the State of Michigan. Copeia 1935(4): 194–195.

—— 1937a. The age, growth, and sex ratio of the Lake Superior longjaw, *Leucichthys zenithicus* (Jordan and Evermann). Pap. Mich. Acad. Sci. Arts Lett. 22 (1936): 691–711.

—— 1937b. The dispersal of smelt, *Osmerus mordax* (Mitchill), in the Great Lakes region. Trans. Amer. Fish. Soc. 66 (1936): 160–161.

—— 1939. The age, growth, sexual maturity, and sex ratio of the common whitefish, *Coregonus clupeaformis* (Mitchill), of Lake Huron. Pap. Mich. Acad. Sci. Arts Lett. 24(2): 195–221.

—— 1942. The age and growth of the Lake Erie white bass, *Lepibema chrysops* (Rafinesque). Pap. Mich. Acad. Sci. Arts Lett. 27(2): 307–334.

—— 1946. Maximum size and age of whitefish. The Fisherman 14(8): 17–18.

—— 1947. Mortality of smelt, *Osmerus mordax* (Mitchill), in lakes Huron and Michigan during the fall and winter of 1942–1943. Trans. Amer. Fish. Soc. 74 (1944): 310–337.

—— 1961. Records, ages, and growth of the mooneye, *Hiodon tergisus*, of the Great Lakes. Trans. Amer. Fish. Soc. 90(2): 170–174.

Van Oosten, J., and H. J. Deason. 1938. The food of the lake trout (*Cristivomer namaycush*) and of the lawyer (*Lota maculosa*) of Lake Michigan. Trans. Amer. Fish. Soc. 67 (1937): 157–177.

Van Oosten, J., and R. Hile. 1949. Age and growth of the lake whitefish, *Coregonus clupeaformis* (Mitchill), in Lake Erie. Trans. Amer. Fish. Soc. 77 (1947): 178–249.

Van Vliet, W. H. MS 1964. An ecological study of *Cottus cognatus* Richardson in northern Saskatchewan. M.A. Thesis. Dep. Biol. Univ. Saskatchewan, Saskatoon, Sask. 155 p.

Vernon, E. H. 1957. Morphometric comparison of three races of kokanee (*Oncorhynchus nerka*) within a large British Columbia lake. J. Fish. Res. Board Canada 14(4): 573–598.

Vernon, E. H., and R. G. McMynn. 1957. Scale characteristics of yearling coastal cutthroat and steelhead trout. J. Fish. Res. Board Canada 14(2): 203–212.

Vincent, R. E. 1960. Experimental introductions of fresh-water alewives. Progr. Fish-Cult. 22(1): 38–42.

Viosca, P., Jr. 1943. Phenomenal growth rates of largemouth black bass in Louisiana waters. Trans. Amer. Fish. Soc. 72 (1942): 68–71.

Vladykov, V. D. 1933. Biological and oceanographic conditions in Hudson Bay. 9. Fishes from the Hudson Bay region (except the Coregonidae). Contrib. Can. Biol. Fish. n.s. 8(2): 13–61.

—— 1942. Two fresh-water fishes new for Quebec. Copeia 1942(3): 193–194.

—— 1945. Trois poissons nouveaux pour la Province de Québec. Natur. Can. 72(1 et 2): 27–39.

—— 1947. Rapport du biologiste du département des pêcheries. Contrib. Que. Dep. Fish. 22: 1–89.

—— 1949a. Quebec lampreys (Petromyzonidae). 1. List of species and their economical importance. Dep. Fish. Prov. Quebec Contrib. 26: 67 p.

—— 1949b. Les cottides d'eau douce du Québec. Annales de l'Acfas 15: 85.

—— 1949c. Captures de poissons d'eau salée en eau douce et de poissons d'eau douce en eau salée dans le Québec. Annales de l'Acfas 15: 85–86.

—— 1950. Larvae of eastern American lampreys (Petromyzonidae). I. Species with two dorsal fins. Natur. Can. 77(3–4): 73–94.

—— 1952. Présence dans le Québec du *Morone americana*, troisième espèce des serranidés. Natur. Can. 79(12): 325–329 + addenda.

—— 1954. Taxonomic characters of the eastern North America chars (*Salvelinus* and *Cristivomer*). J. Fish. Res. Board Canada 11(6): 904–932.

—— 1955a. Fishes of Quebec. Cods. Dep. Fish. Que. Album 4: 12 p.

—— 1955b. Fishes of Quebec. Sturgeons. Dep. Fish. Que. Album 5: 11 p.

—— 1955c. Fishes of Quebec. Eels. Dep. Fish. Que. Album 6: 12 p.

—— 1955d. A comparison of Atlantic sea sturgeon with a new subspecies from the Gulf of Mexico (*Acipenser oxyrhynchus de sotoi*). J. Fish. Res. Board Canada 12(5): 754–761.

—— 1956. Fecundity of wild speckled trout (*Salvelinus fontinalis*) in Quebec lakes. J. Fish. Res. Board Canada 13(6): 799–841.

—— 1957. Les formes locales de la truite rouge du Québec (*Salvelinus marstoni*). Natur. Can. 84(12): 233–248.

—— 1959. The true taxonomic position of the lake trout (*Cristivomer namaycush*). Trans. N.E. Wildlife Conf. 10th Ann. Meet. 1958, Que. Dep. Fish Game. 74 p.

—— 1962. Osteological studies on Pacific salmon of the genus *Oncorhynchus*. Fish. Res. Board Canada Bull. 136: 172 p.

—— 1963. A review of salmonid genera and their broad geographical distribution. Trans. Roy. Soc. Can. ser. 4, 1, sec. 3: 459–504.

—— 1964. Quest for the true breeding area of the American eel (*Anguilla rostrata* LeSueur). J. Fish. Res. Board Canada 21(6): 1523–1530.

—— 1970. Pearl tubercles and certain cranial peculiarities useful in the taxonomy of coregonid genera, p. 167–193. *In* C. C. Lindsey and C. S. Woods [ed.] Biology of coregonid fishes, Univ. Manitoba Press, Winnipeg, Man. 560 p.

Vladykov, V. D., and G. Beaulieu. 1946. Études sur l'esturgeon (*Acipenser*) de la Province de Québec. Natur. Can. 73(6–8): 143–204.

Vladykov, V. D., and W. I. Follett. 1958. Redescription of *Lampetra ayresii* (Günther) of western North America, a species of lamprey (Petromyzontidae) distinct from *Lampetra fluviatilis* (Linnaeus) of Europe. J. Fish. Res. Board Canada 15(1): 47–77.

—— 1965. *Lampetra richardsoni*, a new nonparasitic species of lamprey (Petromyzonidae) from western North America. J. Fish. Res. Board Canada 22(1): 139–158.

—— 1967. The teeth of lampreys (Petromyzonidae): their terminology and use in a key to the holarctic genera. J. Fish. Res. Board Canada 24(5): 1067–1075.

Vladykov, V. D., and J. R. Greeley. 1963. Order Acipenseroidei, p. 24–60. *In* Fishes of the western North Atlantic. Mem. Sears Found. Mar. Res. 1(3): 630 p.

Vladykov, V. D., and R. A. McKenzie. 1935. The marine fishes of Nova Scotia. Proc. Nova Scotia Inst. Sci. 19(1): 17–113.

Vladykov, V. D., and J. M. Roy. 1948. Biologie de la lamproie d'eau douce (*Ichthyomyzon unicuspis*) après la métamorphose. (Résumé). Rev. Can. Biol. 7(3): 483–485.

Vladykov, V. D., and D. H. Wallace. 1952. Studies of the striped bass, *Roccus saxatilis* (Walbaum), with special reference to the Chesapeake Bay region during 1936–38. Bull. Bingham Oceanogr. Collect. 14(1): 132–177.

Vrat, Ved. 1949. Reproductive behavior and development of eggs of the three-spined stickleback (*Gasterosteus aculeatus*) of California. Copeia 1949(4): 252–260.

Wagner, C. C. 1969. Incidence of leech infestation on blacknose dace. Trans. Amer. Fish. Soc. 98(1): 115–116.

Wagner, G. 1910. *Argyrosomus johannae*, a new species of cisco from Lake Michigan. Science, n.s. 31(807): 957–958.

Wainio, A. A. 1962. Rainbow trout in the Nottawasaga River — with specific reference to Nicolston Dam. Ont. Fish Wildlife Rev. 1(4): 19–24.

—— MS 1966. A study of pike (*Esox lucius*, Linnaeus) in two areas of Lake Huron. M.Sc. Thesis. Univ. Toronto, Toronto, Ont. 72 p.

Walbaum, J. J. 1792. Petri Artedi renovati, i.e. bibliotheca et philosophia ichthyologica. Ichthyologiae pars III . . . Grypeswaldiae. Ant. Ferdin. Roese. 723 p.

Walden, H. T. 1964. Familiar freshwater fishes of America. Harper and Row, New York, N.Y. 324 p.

Wales, J. H. 1941. Development of steelhead trout eggs. Calif. Fish Game 27(4): 250–260.

Wallace, C. R. 1967. Observations on the reproductive behavior of the black bullhead (*Ictalurus melas*). Copeia 1967(4): 852–853.

Walters, V. 1953. The fishes collected by the Canadian Arctic Expedition, 1913–1918, with additional notes on the ichthyofauna of western Arctic Canada. Bull. Nat. Mus. Canada 128: 257–274.

—— 1955. Fishes of the western Arctic America and eastern Arctic Siberia. Taxonomy and Zoogeography. Bull. Amer. Mus. Nat. Hist. 106, art. 5: 259–368.

Ward, E. B. 1878. (Lampern in Detroit River). Forest and Stream 11: 222.

Ward, J. C. MS 1951. Breeding biology of the Arctic grayling in the southern Athabaska drainage. M.A. Thesis. Univ. Alberta, Edmonton, Alta.

Wardle, R. A. 1933. The Cestoda of Canadian fishes. III. Additions to the Pacific coastal fauna. Contrib. Can. Biol. Fish. n.s. 8(5): 77–87.

Warner, E. N. 1941. Studies on the embryology and early life history of the gizzard shad, *Dorosoma cepedianum* LeSueur. Abstract Doctoral Dissertation, Ohio State Univ., Columbus, Ohio 34: 637–643.

Warren, B. H. MS 1951. Metazoan parasites of the lake herring, *Leucichthys artedi* LeSueur 1818 from the north shore of Lake Superior. M.Sc. Thesis. Univ. Minnesota Library, St. Paul, Minn.

—— 1952. Report of parasites from the Lake Superior cisco *Leucichthys artedi arcticus*. J. Parasitol. 38(5): 495.

Watling, H., and C. J. D. Brown. 1955. The embryological development of the American grayling (*Thymallus signifer tricolor*) from fertilization to hatching. Trans. Amer. Microsc. Soc. 74(1): 85–93.

Webster, D. A. 1943. Food progression in young white perch *Morone americana* (Gmelin) from Bantam Lake, Connecticut. Trans. Amer. Fish. Soc. 72 (1942): 136–144.

Webster, D. A., W. G. Bentley, and J. P. Galligan. 1959. Management of the lake trout fishery of Cayuga Lake, New York, with special reference to the role of hatchery fish. Mem. Cornell Univ. Agric. Exp. Sta. 357: 83 p.

Weed, A. C. 1927. Pike, pickerel, and muskalonge. Field Mus. Natur. Hist. Zool. Leafl. 9: 52 p.

—— 1934. Notes on the sea trouts of Labrador. Copeia 1934(3): 127–133.

Weisel, G. F. 1954. A rediscovered cyprinid hybrid from western Montana, *Mylocheilus caurinum* × *Richardsonius balteatus balteatus*. Copeia 1954(4): 278–282.

—— 1955a. The osteology of *Mylocheilus caurinum* × *Ptychocheilus oregonense*, a cyprinid hybrid, compared with its parental species. J. Morphol. 96(2): 333–358.

—— 1955b. Three new intergeneric hybrids of cyprinid fishes from western Montana. Amer. Midland Natur. 53(2): 396–411.

—— 1961. Variations in anal fin ray count of a deme of redside shiners, *Richardsonius balteatus*, from a warm spring. Copeia 1961(3): 270–274.

—— 1962. Comparative study of the digestive tract of a sucker, *Catostomus catostomus*, and a predaceous minnow, *Ptychocheilus oregonense*. Amer. Midland Natur. 68(2): 334–346.

Weisel, G. F., and H. W. Newman. 1951. Breeding habits, development and early life history of *Richardsonius balteatus*, a northwestern minnow. Copeia 1951(3): 187–194.

Wells, L. 1966. Seasonal and depth distribution of larval bloaters (*Coregonus hoyi*) in southeastern Lake Michigan. Trans. Amer. Fish. Soc. 95(4): 388–396.

—— 1968. Seasonal depth distribution of fish in southeastern Lake Michigan. U.S. Fish Wildlife Serv. Fish. Bull. 67(1): 1–15.

Wells, L., and A. M. Beeton. 1963. Food of the bloater, *Coregonus hoyi*, in Lake Michigan. Trans. Amer. Fish. Soc. 92(3): 245–255.

Westman, J. R. 1938. Studies on the reproduction and growth of the blunt-nosed minnow, *Hyborhynchus notatus* (Rafinesque). Copeia 1938(2): 57–60.

—— 1952. Lakes, fish and fishing, p. 6–25. *In* New Jersey Fisheries Survey Report No. 1 (1950). N.J. Dep. Conserv. Econ. Dev., Div. Fish Game.

Wheeler, A. 1969. The fishes of the British Isles and north-west Europe. Macmillan Co. Ltd., Toronto, Ont. 613 p.

White, H. C. 1924. A quantitative determination of the number of survivors from planting 5,000 trout fry in each of two streams. Contrib. Can. Biol. Stud. Biol. Sta. Canada n.s. 2(1): 137–149 + 6 fig.

—— 1930. Some observations on the eastern brook trout (*S. fontinalis*) of Prince Edward Island. Trans. Amer. Fish. Soc. 60: 101–108.

—— 1933. Salmon fry in still water. Biol. Board Canada Progr. Rep. Atl. 7: 6–8.

—— 1936. The food of kingfishers and mergansers on the Margaree River, Nova Scota. J. Biol. Board Canada 2(3): 299–309.

—— 1937. Local feeding of kingfishers and mergansers. J. Biol. Board Canada 3(4): 323–338.

—— 1938. The feeding of kingfishers: food of nestlings and effect of water height. J. Fish. Res. Board Canada 4(1): 48–52.

—— 1953. The eastern belted kingfisher in the Maritime Provinces. Fish. Res. Board Canada Bull. 97: 44 p.

—— 1957. Food and natural history of mergansers on salmon waters in the Maritime Provinces of Canada. Fish. Res. Board Canada Bull. 116: 63 p.

White, H. C., J. C. Medcof, and L. R. Day. 1965. Are killifish poisonous? J. Fish. Res. Board Canada 22(2): 635–637.

White, W. J. MS 1970. A study of a population of smallmouth bass *Micropterus dolomieui* (Lacépède) at Baie du Doré, Ontario. M.Sc. Thesis. Univ. Toronto, Toronto, Ont. 83 p.

Whiteaves, J. F. 1886. Catalogue of Canadian Pinnipedia, Cetacea, fishes and marine Invertebrata. Ottawa Dep. Fish. p. 1–42.

Whitehead, P. J. P., and A. C. Wheeler. 1967. The generic names used for the sea basses of Europe and North America (Pisces: Serranidae). Ann. Mus. Civ. Stor. Nat. Genova, 1966–67, 76: 23–41.

Whitehouse, F. C. 1919. Notes on some fishes of Alberta and adjacent waters. Ottawa Natur. 33: 50–55.

Whitley, G. P. 1950. New fish names. Proc. Roy. Zool. Soc. New South Wales for 1948–49. p. 44.

Wich, K., and J. W. Mullan. 1958. A compendium of the life history and ecology of the chain pickerel *Esox niger* (LeSueur). Contrib. to Nat. Acad. Sci. Comm. Handb. Biol. Data 22: 23 p. + biblio.

Wickett, W. P. 1958. Review of certain environmental factors affecting the production of pink and chum salmon. J. Fish. Res. Board Canada 15(5): 1103–1126.

Wier, H. C., and E. P. Churchill. 1946. The anatomy and histology of the digestive system of the gizzard shad *Dorosoma cepedianum* (LeSueur) Proc. S. Dak. Acad. Sci. 25: 34–43 + 8 text-figs.

Wigley, R. L. 1959. Life history of the sea lamprey of Cayuga Lake, New York. U.S. Fish Wildlife Serv. Fish. Bull. 154, Vol. 59: 561–617.

Wilder, D. G. 1947. A comparative study of the Atlantic salmon, *Salmo salar* Linnaeus, and the lake salmon, *Salmo salar sebago* (Girard). Can. J. Res., D, 25: 175–189.

—— 1952. A comparative study of anadromous and freshwater populations of brook trout (*Salvelinus fontinalis* (Mitchill)). J. Fish. Res. Board Canada 9(4): 169–203.

Wilimovsky, N. J. 1954. Checklist of the fishes of Alaska. Stanford Ichthyol. Bull. 4(5): 279–294.

—— [ed.] 1962. Symposium on pink salmon. Inst. Fish. Univ. British Columbia, Vancouver, B.C. 226 p.

Wilimovsky, N. J., and W. O. Freihofer. 1957. Guide to literature on systematic biology of Pacific salmon. U.S. Fish Wildlife Serv. Spec. Sci. Rep. Fish. 209: 266 p.

Williams, I. V., and P. Gilhousen. 1968. Lamprey parasitism on Fraser River sockeye and pink salmon during 1967. Int. Pac. Salmon Fish. Comm. Prog. Rep. 18: 22 p.

Williams, J. E. MS 1955. Determination of age from scales of northern pike (*Esox lucius* L.). Ph.D. Dissertation. Univ. Michigan, Ann Arbor, Mich. 185 p.

Williamson, G. R. 1963. Newfoundland barachois yields two giant trout. Atl. Salmon J. 2: 18–20.

Willock, T. A. 1968. New Alberta records of the silvery and brassy minnows, stonecat and sauger, with a preliminary list of fishes of the Milk River in Alberta. Can. Field-Natur. 82(1): 18–23.

—— 1969. Distributional list of fishes in the Missouri drainage of Canada. J. Fish. Res. Board Canada 26(6): 1439–1449.

Wilmot, S. 1876. The spawning season for black bass. Forest and Stream 6: 195.

Wilson, K. A., and K. Ronald. 1967. Parasite fauna of the sea lamprey (*Petromyzon marinus* von Linne) in the Great Lakes region. Can. J. Zool. 45(6), pt. 1: 1083–1092.

Winchell, A. 1864. Description of a garpike, supposed to be new — *Lepidosteus* (*Cylindrosteus*) *oculatus*. Proc. Acad. Natur. Sci. Philadelphia 16: 183–185.

Winn, H. E. 1953. Breeding habits of the percid fish *Hadropterus copelandi* in Michigan. Copeia 1953(1): 26–30.

—— 1958a. Comparative reproductive behavior and ecology of fourteen species of darters (Pisces–Percidae). Ecol. Monogr. 28(2): 155–191.

—— 1958b. Observations on the reproductive habits of darters (Pisces–Percidae). Amer. Midland Natur. 59(1): 190–212.

—— 1960. Biology of the brook stickleback *Eucalia inconstans* (Kirtland). Amer. Midland Natur. 63(2): 424–438.

Withler, F. C. 1948. Lakes of the Skeena River drainage. 8. Lakes of the Lac-da-dah Basin. Fish. Res. Board Canada Progr. Rep. Pac. 74: 9–12.

—— 1955. Coho salmon fingerling attacked by young lamprey. Fish. Res. Board Canada Progr. Rep. Pac. 104: 15.

WITHLER, I. L. 1956. A limnological survey of Atlin and Southern Tagish lakes. Brit. Columbia Game Comm. Manage. Publ. 5: 36 p.

—— 1966. Variability in life history characteristics of steelhead trout (*Salmo gairdneri*) along the Pacific coast of North America. J. Fish. Res. Board Canada 23(3): 365–393.

WITT, A., JR. 1960. Length and weight of ancient freshwater drum, *Aplodinotus grunniens*, calculated from otoliths found in Indian middens. Copeia 1960(3): 181–185.

WITT, A., JR., and R. C. MARZOLF. 1954. Spawning and behavior of the longear sunfish, *Lepomis megalotis megalotis*. Copeia 1954(3): 188–190.

WOHLSCHLAG, D. E. 1954a. Growth peculiarities of the cisco, *Coregonus sardinella* (Valenciennes), in the vicinity of Point Barrow, Alaska. Stanford Ichthyol. Bull. 4(3): 189–209.

—— 1954b. Mortality rates of whitefish in an arctic lake. Ecology 35(3): 388–396.

WOJCIK, F. J. 1956. Growth and maturation of Arctic grayling in interior Alaska. Proc. 4th Alaskan Sci. Conf. Alaska Div. A.A.A.S., Juneau, Sep. 28–Oct. 3 (1953). p. 83–89.

WOLFERT, D. R. 1969. Maturity and fecundity of walleyes from the eastern and western basins of Lake Erie. J. Fish. Res. Board Canada 26(7): 1877–1888.

WOOLCOTT, W. S. 1962. Infraspecific variation in the white perch, *Roccus americanus* (Gmelin). Chesapeake Sci. 3(2): 94–113.

WORLEY, D. E., and R. V. BANGHAM. 1952. Some parasites of fishes of the upper Gatineau River valley. Ohio J. Sci. 52(4): 210–212.

WORONECKI, D. E. 1969. First record of occurrence of the northern redbelly dace, *Chrosomus eos*, within Prince Edward Island. J. Fish. Res. Board Canada 26(3): 709–710.

WRIGHT, R. R. 1884. Notes on American parasitic Copepoda. Proc. Can. Inst. Toronto 3rd ser. Vol. 1: 249–253.

—— 1892. Preliminary report on the fish and fisheries of Ontario, p. 419–476. *In* Ont. Game Fish Comm., Comm. Rep.

WYNNE-EDWARDS, V. C. 1932. The breeding habits of the black-headed minnow (*Pimephales promelas* Raf.). Trans. Amer. Fish. Soc. 62 (1932): 382–383.

—— 1947. The Yukon territory, p. 5–20; The Mackenzie River, p. 21–30. *In* Northwest Canadian Fisheries Surveys in 1944–1945. Fish. Res. Board Canada Bull. 72: 94 p.

—— 1952. Fishes of the Arctic and subarctic, p. 5–24. *In* Freshwater vertebrates of the Arctic and subarctic. Fish. Res. Board Canada Bull. 94: 28 p.

YARRELL, W. 1836. A history of British fishes. Vol. 2. John Van Voorst, London. 472 p. + suppl. 72 p.

YERGER, R. W. 1953. Yellow bullhead preyed upon by cottonmouth moccasin. Copeia 1953(2): 115.

YOUNG, R. T., and L. J. COLE. 1900. On the nesting habits of the brook lamprey (*Lampetra wilderi*). Amer. Natur. 34(404): 617–620.

INDEX

INDEX OF COMMON AND SCIENTIFIC NAMES

- *Abramis balteatus* 506
  - *crysoleucas* 438
  - *lateralis* 506
- (*Abramis*) *balteatus, Cyprinus* 506
- (*Abramis?*) *smithii, Cyprinus* 331, 332, 336
- achigan à grande bouche 740
- achigan à petite bouche 734
- *achigan, Bodianus* 733
- *Acipenser* 78
  - *acutirostris* 91
  - *aleutensis* 100
  - *atelaspis* 89
  - *athracinus* 89
  - *brevirostris* 82
  - *brevirostrum* **80–82**
  - *buffalo* 89
  - *carbonarius* 89
  - *fulvescens* **82–89**
  - *fulvescens acutirostris* 83, 89
  - *fulvescens obtusirostris* 83, 89
  - *kirtlandi* 89
  - *laevis* 89
  - *lamarii* 89
  - *maculosus* 89
  - *medirostris* **90–92**
  - *megalaspis* 89
  - *oxyrhynchus* **92–96**
  - *oxyrhynchus de sotoi* 93
  - *oxyrhynchus oxyrhynchus* 96
  - *rhynchaeus* 89
  - *rosarium* 89
  - *rubicundus* 89
  - *Rupertianus* 89
  - *sturio* 89, 93, 96
  - *sturio oxyrhynchus* 96
  - *transmontanus* **96–100**
- Acipenseridae 77, 78
  - key to 78
- Acipenseriformes 77
- *Acrocheilus alutaceum* 388
  - *alutaceus* **386–388**
  - *xestes* 386
- *Acrochilus alutaceus* 388
- *aculeatus, Gasterosteus* **665–668**
- *aculeatus leiurus, Gasterosteus* 665
- *aculeatus trachurus, Gasterosteus* 665
- *acuta, Perca* 761
- *acutirostris, Acipenser* 91
  - *Acipenser fulvescens* 83, 89
- *acutus, Notropis atherinoides* 440
- *aenea, Cichla* 707
- *aeneus, Centrarchus* 707
- *aestivalis, Alosa* **119–120**
  - *Clupea* 120
  - *Pomolobus* 120
- *Agosia falcata* 500
  - *oscula* 502
  - *shuswap* 500
- *aguabonita, Salmo* 185
- *alascanus, Argyrosomus* 255, 256
  - *Leucichthys* 256
- Alaska blackfish **338–341**
- *albatrossis, Osmerus* 324
- *albeolus, Notropis* 459
- *albidus, Labrax* 692
- *Alburnellus jaculus* 443
- *Alburnops blennius* 447
  - *heterodon* 456
- *Alburnus nitidus* 443
  - *rubellus* 443, 466
  - *rubrifrons* 466
  - *umbratilis* 473
- *albus, Coregonus* 243, 277
- *aleutensis, Acipenser* 100
- Aleutian sculpin 822
- *aleuticus, Cottus* **820–822**
- alewife **120–128**
- *alipes, Salmo* 202, 207
  - *Salvelinus* 207
- Allegheny pearl dace 516
- *Alosa aestivalis* **119–120**
  - *cyanonoton* 120
  - *pseudoharengus* **120–128**
  - *sapidissima* **128–132**
  - *tyrannus* 128
  - *vernalis* 128
- alose 132
- alose à gésier 137
- alose d'été 120
- alose savoureuse 132
- *alosoides, Amphiodon* 331
  - *Hiodon* **327–332**, 336
  - *Hyodon* 331
- *alpenae, Coregonus* 230, 231, **234–236**
  - *Leucichthys* 236
- *alpestris, Salmo clarkii* 179, 183
- alpine char 207
- *alpinus malma, Salvelinus* 215, 219
- *alpinus, Salmo* 207
  - *Salvelinus* **201–207**
- *alutacea, Lavinia* 388
- *alutaceum, Acrocheilus* 388
- *alutaceus, Acrocheilus* **386–388**
  - *Acrochilus* 388
- *alveoides, Amphiodon* 331, 332
- *Alvordius aspro* 805

  maculatus 805
amarus, Notropis hudsonius 460
Ambloplites rupestris **703–707**
  rupestris ariommus 704
  rupestris rupestris 704, 707
Amblyopsidae 677
Amblyopsiformes 677
Ameiurus 605
  lacustris 603, 605, 610
  melas 594
  melas melas 594
  natalis 598
  nebulosus 603
  vulgaris 594, 603
amentus, Esox 365, 369
American bream 438
American brook lamprey 58, **62–65**
American burbot 645
American chub 515
American eel **624–629**
American grayling 305
American perch 761
American roach 438
American shad **128–132**
American smelt 317
Americana, Lucio-perca 774
  Lucioperca 774
americana, Lucioperca 766
  Morone **684–689**
  Perca 689, 761
americanus, Esox 353
  Esox americanus **348–351**, 353
  Esox lucius β 351
  Perca 761
  Roccus 689
Americanus, Leucosomus 438
  Petromyzon 75
americanus umbrosus, Esox 355
americanus vermiculatus, Esox **352–355**
amethystus, Salmo 227
Amia calva 111, **112–116**
  canina 116
  occidentalis 116
  ocellicauda 116
  ocellicaudata 116
  thompsoni 116
Amiidae 101, 111
Amiiformes 111
Amiurus 605
  borealis 610
  catus 603
  caudifurcatus 610
  natalis 598
  nebulosus 603
  vulgaris 603
Ammocoetes argenteus 54
  aureus 61
  borealis 51, 54
  concolor 54
  hirudo 54
  unicolor 51
Ammocrypta (Ammocrypta) pellucida 776
  pellucida **775–776**
amnigenus, Tirodon 420
Amphiodon alosoides 331
  alveoides 331, 332
Anacanthini 640
Anguilla 623
  anguilla 624
  Bostoniensis 628
  chrysypa 628
  muraena 628
  novaeterrae 628
  punctatissima 628
  rostrata **624–629**
  tenuirostris 628
  vulgaris 628
anguilla, 605
  Anguilla 624
  Muraena 628
anguille d'Amérique 629
Anguillidae 623
Anguilliformes 623
angusticeps, Coregonus 487
anisura, Myxostoma 567
anisurum, Moxostoma **564–567**, 578, 586
anisurus, Catostomus 567
annularis, Pomoxis **741–744**
anogenus, Hybopsis 439
  Notropis **438–439**, 454
anomalum, Campostoma 378
apeltes, Gasterosteus 660
Apeltes quadracus **658–660**
Aphredoderidae 677
Aplites salmoides 740
Aplodinotus grunniens **812–816**
Apocope falcata 500
  oscula 502
Apodes 623
Apomotis cyanellus 710, 713
appendix, Entosphenus 64
  Lethenteron 64
  Petromyzon 64
  Pomotis 710
arctic char **201–207**, 215
arctic charr 207
arctic cisco **244–246**
arctic grayling, **300–305**
  sailfin 305
Arctic lamprey **58–61**
Arctic Ocean smelt 312
Arctic rainbow smelt 312

arctic salmon 207
arctic trout 305
arcticus pallasi, Thymallus 304
arcticus, Salmo 304
    Thymallus **300–305**
arcticus signifer, Thymallus 304
arcturus, Salmo 207
    Salvelinus 207
ardens, Catostomus 550
argentatus, Salmo irideus 185, 191
argentea, Muraena 628
argenteus, Ammocoetes 54
    Ichthyomyzon 48
    Leuciscus 514
    Petromyzon 54
Argenteus, Ichthyomyzon 54
Argyreus nasutus 498
    osculus 502
argyritis, Hybognathus 417
Argyrosomus alascanus 255, 256
    artedi 243
    eriensis 243
    hoyi 250, 252
    huronius 243
    johannae 252
    laurettae 256
    nigripinnis 259
    prognathus 236, 250, 259
    pusillus 264
    tullibee 243
    zenithicus 268
ariommus, Ambloplites rupestris 704
artedi, Argyrosomus 243
    Leucichthys 243
Artedi, Coregonus 243
    Salmo (*Coregonus*) 243
artedii, Coregonus 230, **236–243**, 244, 257, 266, 270
asper, Centridermichthys 825
    Cottopsis 825
    Cottus **823–826**
aspro, Alvordius 805
    Etheostoma 805
    Hadropterus 805
atelaspis, Acipenser 89
athabascae, Coregonus 237
    Leucichthys 266, 268
    Semotilus margarita 516
Atherina mordax 317
Atherinidae 651
Atheriniformes 651
Atherinoidei 651
atherinoides acutus, Notropis 440
atherinoides, Notropis 383, **440–443**
    Notropis atherinoides 440
athracinus, Acipenser 89
atikameg, Coregonus 277
atkinsi, Gasterosteus 668
atkinsii, Gasterosteus 668
Atkinsii, Gasterosteus 668
Atlantic eel 629
Atlantic rainbow smelt 312
Atlantic salmon, **192–197**, 198, 202
    common 197
Atlantic shad 132
Atlantic smelt, North American 312
Atlantic sturgeon **92–96**
Atlantic tomcod **646–649**
Atlantic whitefish **281–282**
Atractosteus 101
atrarius, Pimelodus 603
atratulus, Cyprinus 494
    Rhinichthys **491–494**
    Rhinichthys atratulus 491
atratulus meleagris, Rhinichthys 491
atricada, Hydrargyra 345
atricauda, Hydrargyra 345
atromaculatus, Cyprinus 511
    Etheostoma olmstedi 794
    Leuciscus 511
    Semotilus **507–511**
    Semotilus atromaculatus 508
atromaculatus thoreauianus, Semotilus 508
atronasus, Cyprinus 494
    Leuciscus 494
    Rhinichthys 494
auratus, Carassius **389–391**
    Cyprinus 391
    Notemigonus crysoleucas 435
aurea, Lampetra 61
Aureoleum, Moxostoma 583
aureolum, Moxostoma 580, 583, 585, 586
aureolus, Catastomus 583
    Cyprinus (*Catastomus*) 583
    Salvelinus 202, 207
aureus, Ammocoetes 61
auritus, Eupomotis 710
    Labrus 710
    Lepomis **707–710**
Auritus, Lepomis 723
aurora, Catostomus 535
aurora trout 209, 213
autumnalis, Coregonus **244–246**, 255
    Leucichthys 246
    Salmo 244
    Salmo (*Coregonus*) 246
ayresi, Lampetra **55–57**
ayresii, Lampetra 57
    Petromyzon 56, 57

Back's grayling 305
Baione 209

  - *fontinalis* 213
- *bairdi, Cottus* **826–830**, 831, 836
  - *Cottus bairdi* 827
- *bairdi kumlieni, Cottus* 827
- *bairdii, Cottus* 830
  - *Salmo* 219
  - *Salvelinus* 219
- *balteatus, Abramis* 506
  - *Cyprinus* (*Abramis*) 506
  - *Leuciscus* 506
  - *Richardsonius* **503–507**
- *balteatus lateralis, Leuciscus* 506
- banded darter 782
- banded killifish, **631–634**
  - eastern 632, 634
  - western 634
- banded pickerel 351
- bang 128
- banstickle 668
- bar blanc 692
- bar-perche 689
- bar rayé 697
- barbotte brune 604
- barbotte des rapides 614
- barbotte jaune 598
- barbotte noire 594
- barbue de rivière 610
- barred fantail 787
- barred minnow 634
- bass, 689, 740
  - black 734, 740
  - brown 734
  - calico 749
  - grass 749
  - green 734, 740
  - large mouth 740
  - large mouthed 740
  - largemouth **734–740**
  - largemouth black 740
  - narrow-mouthed 689
  - northern largemouth 735, 740
  - northern rock 704, 707
  - northern smallmouth 734
  - Oswego 749
  - Red River 816
  - redeye 707
  - rock **703–707**
  - silver 692, 744, 816
  - smallmouth **728–734**
  - smallmouth black 734
  - speckled 749
  - spotted 733
  - strawberry 749
  - striped **693–697**
  - striper 697
  - sun 718
  - white **689–692**, 744
- "bass, gray" 816
- "basse, little white" 689
- Basses, 699
  - Sea 683
  - Temperate 683
  - Temperate, key to 684
- (*Bathysudis*) *parri, Lestidium* 324
- *bdellium, Ichthyomyzon* 48, 54
- *beadlei, Synechoglanis* 610
- Bear Lake bullhead 835
- Bear Lake herring 243
- beaverfish 116
- bec-de-lièvre 414
- beetle-eye 614
- Beloniformes 651
- *bendirei, Cottus* 830
- Bering cisco **255–256**
- *biaculeatus, Gasterosteus* 668, 671
- *bifrenatus, Hybopsis* 445
  - *Notropis* **444–445**
- big-eye Mackenzie herring 265
- big-eyed herring 128
- bighead sucker 557
- bigmouth buffalo **557–560**
- bigmouth shiner 452
- *biguttata, Hybopsis* 430
- *biguttatus, Nocomis* **427–430**
  - *Semotilus* 430
- billfish 105, 109
- *bison, Lepisosteus* 109
- *bispinosus cuvieri, Gasterosteus* 671
- *bispinosus, Gasterosteus* 668, 671
- bitterhead 438
- *biwa, Oncorhynchus* 146
- black-back tullibee 259
- black bass, 734, 740
  - largemouth 740
  - smallmouth 734
- black brook lamprey, small 65
- black buffalo 560
- black bullhead, **591–594**, 603, 605
  - northern 592
- black catfish 594
- black chain pike 374
- black crappie 744, **745–749**
- black-fin tullibee 259
- black lamprey, small 65
- black mullet 543, 573
- black-nosed minnow 459
- black redhorse **571–573**
- black salmon 197
- black-sided darter 805
- black sturgeon 83
- black sucker 535, 543, 557, 562
- blackbelly 120

blackchin shiner **454–456**
blackfin 259
blackfin cisco 231, **256–259**
blackfish, 116, 341
    Alaska **338–341**
blackhead minnow 484
blacknose dace, 459, **491–494**
    eastern 491, 494
    western 491
blacknose shiner, **456–459**
    northern 459
blackside darter 798, **803–805**
blackspot chub 511
blackspot stickleback 671
blackspotted stickleback **669–671**
blear-eyed herring 128
blennioides, Diplesion 779
    Etheostoma **777–779**
    Etheostoma blennioides 777
blennioides pholidotum, Etheostoma 778
blennius, Alburnops 447
    Hybopsis 447
    Notropis **446–447**, 452, 469
blennius jejunus, Notropis 446
bloat 250
bloater 230, 231, **246–250**
blob, 830
    deep-water 847
blood sucker 51
bloody stickleback 660
blue bream 724
blue catfish 609
blue darter 782
blue pickerel 767
blue pike 752, 767, 768
blue pike perch 767
blue sunfish 724
blue walleye 768, 773
blueback 120, 164, 171, 243
blueback herring **119–120**
blueback salmon 171
blueback trout 207
blueback tullibee 243
bluefin 259
bluefish 305
bluegill, 709, 713, **719–724**, 727
    common 720, 724
bluegill bream 724
bluegill sunfish, 724
    northern 724
bluehead sucker 542
bluntnose minnow **476–479**
Bodianus achigan 733
    rupestris 707
Boleichthys exilis 786
    fusiformis 786
boleoides, Uranidea 835
Boleosoma maculatum 797
    nigrum 797
    nigrum eulepis 793
    nigrum nigrum 793
    nigrum olmstedi 793
(Boleosoma) nigrum, Etheostoma 753, 793
bony sturgeon 89
"boreal smelt" 312
boreale, Etheostoma 786
borealis, Amiurus 610
    Ammocoetes 51, 54
    Lampetra 61
    Opsopoeodus 463
    Petromyzon 61
    Poecilichthys 786
    Silurus 605
    Silurus (Pimelodus) 610
boreum, Stizostedion canadense 763
Boreus, Esox 363
bosci, Notemigonus crysoleucas 435
Bostoniensis, Anguilla 628
    Catostomus 543
    Muraena 628
bottlefish 406
bouche coupante 388
Bowfin 111
bowfin **112–116**
branch herring 128
branchialis, Petromyzon 68
brassy minnow **414–416**
bratan 197
breac 201, 213
bream, 438, 724
    American 438
    blue 724
    bluegill 724
    red-sided 507
brevicauda, Salmo 183
breviceps, Lepomis megalotis 725
    Moxostoma 580, 583
brevirostris, Acipenser 82
    Thymallus 301
brevirostrum, Acipenser **80–82**
bridgelip sucker **536–538**, 546
bridle shiner **444–445**
bridled shiner 445
brindled madtom 618, **619–621**
brindled stone-cat 621
broad mullet 531
broad whitefish **278–280**
brochet 363
brochet d'Amérique 351
brochet maillé 374
brochet vermiculé 355
bronze minnow 399

- brook char, Pacific 219
  - western 219
- brook chub 511
- brook lamprey, 51, 55, 65
  - American 58, **62–65**
  - European 65
  - Michigan 51
  - nonparasitic 68
  - northern **49–51**
  - small black 65
  - southern 46
  - western 57, **65–68**
- brook minnow 494
- brook silverside **652–654**
- brook silversides 654
- brook stickleback **661–664**
- brook trout 170, **208–213**, 218, 221
  - common 213
  - Eastern 213
  - Pacific 219
  - sea-run 208
  - western 219
- brookie 213
- brown bass 734
- brown bullhead 596, **598–604**
  - northern 604
- brown catfish 604
- brown sturgeon 83
- brown trout, **197–201**, 209
  - English 201
  - European 201
  - German 198, 201
- brownback whitefish 285
- brownie 201
- *bubalus, Ictiobus* 560
- *Bubalus, Ictiobus* 560
- *buchanani, Notropis volucellus* 474
- buffalo, 560
  - bigmouth **557–560**
  - black 560
  - gourdhead 560
  - redmouth 560
  - smallmouth 560
- *buffalo, Acipenser* 89
- buffalo à grande bouche 560
- buffalofish, 560
  - common 560
- bull trout 219
- *bullaris, Cyprinus* 514
  - *Semotilus* 514
- bulldog pickerel 351
- bullhead, 598, 604, 826
  - Bear Lake 835
  - black **591–594**, 603, 605
  - brown 596, **598–604**
  - common 604
  - marbled 604
  - northern black 592
  - northern brown 604
  - northern yellow 598
  - prickly 826
  - yellow **595–598**
  - yellow belly 594
- burbot, 605, **641–645**
  - American 645
- burnstickle, tiny 674
- butterfish 438

- *caerulea, Etheostoma* 782
- *caeruleum, Etheostoma* **780–782**
  - *Etheostoma caeruleum* 781
- *caeruleum notiale, Etheostoma* 781
- *caeruleum oreium, Etheostoma* 781
- *caeruleus, Oligocephalus* 782
  - *Poecilichthys* 782
- calico bass 749
- *calva, Amia* 111, **112–116**
- *Campbelli, Salmo* 219
- *Campostoma anomalum* 378
- Camus 89
- *canadense boreum, Stizostedion* 763
- *canadense griseum, Stizostedion* 763, 766
- *canadense, Stizostedion* **762–767**
  - *Stizostedion canadense* 763, 766
  - *Stizostethium (Cynoperca)* 766
- *Canadense, Stizostedion* 766
  - *Stizostethium* 766
- *canadense, Stizostedium* 766
- *canadensis, Coregonus* **281–282**
  - *Leuciscus* 514
  - *Salmo* 213
- *Canadensis, Lucio-perca* 766
  - *Lucioperca* 766, 774
- candlefish 324
- *canina, Amia* 116
- *canis, Oncorhynchus* 157
  - *Salmo* 157
- *cantharus nigro-maculatus* 749
- *caprodes carbonaria, Percina* 798
- *caprodes, Etheostoma* 800
  - *Percina* **797–800**
  - *Percina caprodes* 798
  - *Sciaena* 800
- *caprodes semifasciata, Percina* 798
- *Carassius* 376
  - *auratus* **389–391**
- *carbonaria, Percina caprodes* 798
- *carbonarius, Acipenser* 89
- *carinatum, Moxostoma* **567–570**
- *carinatus, Placopharynx* 570
- *carletoni, Leuciscus* 519

carolinae, Cottus 837
carp, 389, **407–411**, 531, 543
  European 411
  German 411
  golden 391
  lake 531
  leather 411
  mirror 411
  silver 531
  sucking 463
  white 531
carpe 411
carpio, Catostomus 567, 578, 586
  Cyprinus **407–411**
  Myxostoma 567, 578
Carpio, Cyprinus 411
Carpiodes cyprinus **528–531**
  Cyprinus 530
  cyprinus cyprinus 530
  forbesi 529
  thompsoni 529
  Thompsoni 530
  velifer 529, 530
Carps, Minnows *or* 376
  key to 378
carpsucker, 531
  eastern 531
  quillback 531
Caspiomyzon 36
castaneus, Ichthyomyzon **46–48**, 54
cat, channel 610
  speckled 116
  tadpole 618
  white 614
cataphractus, Gasterosteus 668
cataractae, Gobio 498
  Rhinichthys **494–498**
Catastomus aureolus 583
  communis 543
  Forsterianus 535
  Hudsonius 543
  Lesueurii 583
  Sueuri 583
(*Catastomus*) *aureolus, Cyprinus* 583
(*Catastomus*) *Forsterianus, Cyprinus* 535
(*Catastomus*) *Hudsonius, Cyprinus* 463, 543
(*Catastomus*) *reticulatus, Cyprinus* 535, 543
(*Catastomus*) *Sueuril, Cyprinus* 583
catfish, 604, 614
  black 594
  blue 609
  brown 604
  channel **604–610**
  common 604
  flathead 609
  Great Lake 605, 610
  Great Lakes 610
  lake 610
  northern 610
  spotted 605, 610
  stone 614
  white 609
  yellow 598
Catfishes 588
  key to 589
Catonotus flabellaris 789
Catostomidae 523
  key to 524
Catostomus anisurus 567
  ardens 550
  aurora 535
  Bostoniensis 543
  carpio 567, 578, 586
  catostomus 523, **531–535**, 539
  catostomus catostomus 535
  catostomus lacustris 532, 535
  catostomus nannomyzon 532
  catostomus pocatello 532
  catostomus rostratus 535
  chloropteron 539
  columbianus **536–538**
  columbianus columbianus 537
  columbianus hubbsi 537
  columbianus palouseanus 537
  commersoni **538–543**, 545
  commersoni suckleyi 539, 542
  commersonii 543
  commersonnii 543
  commersonnii commersonnii 543
  commersonnii utawana 539
  communis 535, 539, 543
  cyprinus 530
  Cyprinus 530
  discobolus 550
  Duquesnii 573
  erythrurus 576
  flexuosus 539
  forsterianus 535
  Forsterianus 539, 543
  gracilis 539
  griseus 535
  hudsonius 535
  longirostris 535, 539
  macrocheilus **544–547**
  macrolepidotum 583
  melanops 562
  nigricans 556
  pallidus 539
  platyrhynchus 537, **547–550**
  reticulatus 539
  richardsoni 543
  syncheilus 537, 538

    tahoensis 550
    teres 539, 543
    tuberculatus 553
catostomus, Catostomus 523, **531–535**, 539
    Catostomus catostomus 535
    Cyprinus 535
Catostomus, Cyprinus 535
catostomus lacustris, Catostomus 532, 535
catostomus nannomyzon, Catostomus 532
catostomus pocatello, Catostomus 532
catostomus rostratus, Catostomus 535
catulus, Ictalurus melas 592
catus, Amiurus 603
    Pimelodus 603
caudifurcatus, Amiurus 610
caurina, Clarkina 427
caurinus, Cyprinus (*Leuciscus*) 427
    Mylocheilus **424–427**
cayuga, Notropis 459
central johnny darter 793, 797
central mudminnow **341–345**
central redfin pickerel 355
Centrarchidae 699, 751
    key to 700
Centrarchus aeneus 707
    fasciatus 733
Centridermichthys asper 825
    gulosus 826
    parvus 826
Cepediana, Megalops 137
cepedianum, Dorosoma **133–137**
    Dorosoma cepedianum 133
cepedianum exile, Dorosoma 134
cepedianum heterurum, Dorosoma 133
cephalus, Leuciscus 406, 511
Ceratichthys micropogon 433
    Plumbeus 406
    prosthemius 406
chabot à tête courte 836
chabot à tête plate 842
chabot côtier 822
chabot de profondeur 847
chabot de torrent 838
chabot piquant 826
chabot tacheté 830
chabot visqueux 835
chain pickerel 351, 361, **370–374**
chain pike, black 374
chamberlaini, Cottus 835
channel cat 610
channel catfish **604–610**
channel darter 798, **801–802**
char, alpine 207
    arctic **201–207**, 215
    Dolly Varden 219
    European 207
    Great Lakes 227
    Pacific brook 219
    red spotted 219
    sea 219
    speckled 213
    western brook 219
charbonnier 89
charr, arctic 207
    Dolly Varden 219
    Greenland 207
Chars, salmon, trouts *and* 144
Chars, whitefishes, grayling, salmons, trouts *and*, key to 139
chat-fou brun 618
chat-fou tacheté 621
chatte de l'est 438
Chërnaya ryba 341
chestnut lamprey **46–48**
chinook 163, 177
chinook salmon 146, 163, **172–177**
Chirostoma sicculum 654
chiselmouth **386–388**
chivin 515
chloropteron, Catostomus 539
Chondrostei 77
Chondrosteidae 77
choquemort 639
chouicha, Oncorhynchus 177
choupique! 116
Chrosomus 377
    dakotensis 395
    eos **392–395**, 397
    erythrogaster 393, 395
    neogaeus 393, **396–399**
chrysocephalus, Notropis 383, 449
chrysoleucas, Cyprinus (*Leuciscus*) 438
    Leuciscus 438
    Notemigonus 438
chrysops, Lepibema 692
    Morone **689–692**
    Perca 692
    Roccus 692
chrysopsis, Elattonistius 331
    Hiodon 331, 336
    Hyodon 331
chrysypa, Anguilla 628
chub, 254, 438, 511, 515, 639
    American 515
    blackspot 511
    brook 511
    common 511
    creek 406, **507–511**
    crested 433
    deepwater 252
    eastern river 433
    flathead **484–487**

  gravel **423–424**
  hornyhead **427–430**, 432
  lake **401–406**
  lake northern 406
  longjaw 236
  mohawk 515
  mud 511
  northern 406
  northern creek 511
  northern flathead 485
  peamouth 427
  Reighard's 262
  river 428, **431–433**
  roughnosed 515
  shortjaw 268
  shortnose 262
  silver **420–422**, 682
  silvery 511, 515
  southern flathead 485
  spotted 424
  Storer's 422
  the 252
  white 515
chub minnow 406
chub sucker 553
"chubs" 231
chubsucker, 553
  lake **551–553**
  western lake 553
chum 158
chum salmon 146, 151, **153–158**
churchillensis, Leucichthys 243
cibaria, Lampetra 57
Cichla aenea 707
  fasciata 733
  minima 733
ciliatus, Entosphenus tridentatus 42
cisco, **236–243**, 265, 282
  arctic **244–246**
  Bering **255–256**
  blackfin 231, **256–259**
  common 243
  deepwater 230, **250–252**
  Hoy's 250
  least **262–265**
  longjaw 230, **234–236**
  mooneye 259
  Reighard 262
  shallowwater 243
  shortjaw 231, **265–268**
  shortnose 230, **260–262**
cisco à grande bouche 236
cisco à mâchoires égales 268
cisco à museau court 262
cisco à nageoires noires 259
cisco arctique 246
cisco de fumage 250
cisco de lac 243
cisco de l'Alaska 256
cisco de profondeur 252
cisco du Béring 256
cisco kiyi 254
cisco sardinelle 265
ciscoe 243
Ciscoes 230
clarki lewisi, Salmo 183
clarki, Salmo **177–183**
  Salmo clarki 183
clarkii alpestris, Salmo 179, 183
clarkii, Fario 182
  Salmo 183
  Salmo clarkii 183
clarkii lewisi, Salmo 183
Clarkii, Salmo 182
Clarkina caurina 427
Clark's trout 183
Clinostomus elongatus **399–401**, 508
  margarita 518
clodalis, Hiodon 336
Clodalis, Hiodon 331
Clupea aestivalis 120
  hudsonia 463
  pseudo harengus 128
  sapidissima 132
  vernalis 128
clupeaformis, Coregonus **269–277**, 278, 282
  Salmo 269, 277
Clupeidae 117
  key to 118
Clupeiformes 117
clupeiformis, Coregonus 243, 277
coarse scaled sucker 543
coarsescale sucker 547
coast rainbow trout 191
coastal cut-throat trout 183
coastal cutthroat 183
coaster 213
coastrange sculpin **820–822**
Cobitis heteroclita 638
cockatouch 835
cod, freshwater 645
  Pacific 157
  tommy 649
  winter 649
Codlike fishes 640
Cods 640
  key to 641
coenosus, Pimelodus 598
  Silurus (Pimelodus) 598, 603
coerulea, Etheostoma 782
coeruleum, Etheostoma 782
coeruleus, Poecilichthys 782

cognatus, Cottus 872, **830–835**
  Cottus cognatus 831
cognatus gracilis, Cottus 827, 831
coho 164, 176
coho salmon 146, **158–164**
Colorado squawfish 488
Columbia River dace 490
Columbia River minnow 507
Columbia River sucker 547
Columbia sculpin 830
Columbia small scaled sucker 538
Columbia squawfish 490
Columbia sturgeon 100
Columbia transmontanus 678
columbianus, Catostomus **536–538**
  Catostomus columbianus 537
  Pantosteus 537
columbianus hubbsi, Catostomus 537
columbianus palouseanus, Catostomus 537
commersoni, Catostomus **538–543**, 545
commersoni suckleyi, Catostomus 539
commersonii, Catostomus 543
commersonnii, Catostomus 543
  Catostomus commersonnii 543
Commersonnii, Cyprinus 543
commersonnii utawana, Catostomus 539
common Atlantic salmon 197
common bluegill 720, 724
common brook trout 213
common buffalofish 560
common bullhead 604
common catfish 604
common chub 511
common cisco 243
common eel 629
common emerald shiner 443
common freshwater stickleback 664
common garpike 109
common killifish 639
common mullet 583
common mummichog 639
common redhorse 580, 583, 586
common shad 132
common shiner **448–452**
common slimy muddler 835
common stickleback 664, 668
common sturgeon 89, 96
common sucker 543
common sunfish 718
common white sucker 543
common whitefish 277
communis, Catastomus 543
  Catostomus 535, 539, 543
  Pogonichthys 487
concinnus, Gasterosteus 674
concolor, 51
  Ammocoetes 54
  Ichthyomyzon 48, 54
  Petromyzon 54, 70, 75
confertus, Pimephales promelas 481
confinis, Salmo 227
confusus, Cottus **835–836**
Connecticut River shad 132
connie 298
conny 298
consuetus, Oncorhynchus 157
  Salmo 157
Cooperi, Oncorhynchus 177
cooperi, Salmo 177
copelandi, Cottogaster 802
  Hadropterus 802
  Percina **801–802**
  Rheocrypta 802
Copeland's darter 802
copii, Leuciscus 443
Copper-mine River salmon 207
copper redhorse **577–578**
corégone tschir 280
Coregonidae 230
Coregoninae 138, 230
Coregonus 230
  albus 243, 277
  alpenae 230, 231, **234–236**
  angusticeps 487
  Artedi 243
  artedii 230, **236–243**, 244, 257, 266, 270
  athabascae 237
  atikameg 277
  autumnalis **244–246**, 255
  canadensis **281–282**
  clupeaformis **269–277**, 278, 282
  clupeiformis 243, 277
  coulteri 285
  coulterii 285
  entomophagus 237
  hoyi 230, 231, **246–250**
  johannae 230, 231, **250–252**
  kennicotti 277, 278, 280
  kiyi 230, 231, **252–254**, 257
  kiyi kiyi 253
  kiyi orientalis 253
  labradoricus 277, 282
  latior 277
  laurettae 244, **255–256**
  macrognathus 237
  nasus 270, **278–280**
  nasus kennicotti 280
  nelsoni 270
  nelsonii 277
  nigripinnis 231, **256–259**
  nigripinnis cyanopterus 257
  nigripinnis nigripinnis 257

    nigripinnis prognathus 257
    nigripinnis regalis 257
    nipigon 237
    odonoghuei 277
    pidschian 270
    prognathus 257, 259
    pusillus 263, 264
    quadrilateralis 290, 291
    reighardi 230, 231, **260–262**
    reighardi dymondi 260
    reighardi reighardi 260
    sapidissimus 277
    sardinella **262–265**
    Signifer 304
    sp. 282
    spp. 474
    Thymalloides 304
    tullibee 244, 257
    williamsoni 294
    zenithicus 231, 237, **265–268**
(*Coregonus*) *Artedi, Salmo* 243
(*Coregonus*) *autumnalis, Salmo* 246
(*Coregonus*) *harengus, Salmo* 243
(*Coregonus*) *Labradoricus, Salmo* 277
coregonus, Moxostoma 580
(*Coregonus*) *quadrilateralis, Salmo* 291
(*Coregonus*) *tullibee, Salmo* 243
cornutus, Cyprinus 451
    Leuciscus 451
    Luxilus 452
    Minnilus 451, 452
    Notropis 428, 432, **448–452**, 508, 513
corporal 515
corporalis, Cyprinus 514
    Leucosomus 514, 516
    Semotilus **511–515**
Corvina oscula 816
    Richardsonii 816
(*Corvina*) *oscula, Sciaena* 816
Cottidae 817
    key to 818
Cottogaster copelandi 802
    shumardi 808
cottonfish 116
Cottopsis asper 825
    parvus 825
    ricei 842
Cottus 817
    aleuticus **820–822**
    asper **823–826**
    bairdi **826–830**, 831, 836
    bairdi bairdi 827
    bairdi kumiieni 827
    bairdii 830
    Bairdii 830
    bendirei 830
    carolinae 837
    chamberlaini 835
    cognatus 827, **830–835**
    cognatus cognatus 831
    cognatus gracilis 827, 831
    confusus **835–836**
    formosus 835
    Franklini 835
    girardi 830
    gobio 839
    gracilis 835
    hubbsi 830
    ictalops 830
    meridionalis 830
    onychus 842
    philonips 835
    pollicaris 842
    protrusus 820, 822
    quadricornis 846
    rhothea 838
    rhotheus **837–838**, 839
    ricei 837, **839–842**
    Richardsoni 830
    sibiricus 839
    sp. 341, 836
    spinulosus 839
Couesius 377, 516
    greeni 406
    plumbeus 397, **401–406**, 519
    plumbeus dissimilis 403
    plumbeus greeni 403
    plumbeus plumbeus 403
    plumbeus rubrilateralis 519
    prosthemius 406
couette 531
coulteri, Coregonus 285
    Prosopium **282–285**
coulterii, Coregonus 285
    Prosopium 285
Coulter's whitefish 285
Cranbrook trout 179
crapet à longues oreilles 727
crapet arlequin 724
crapet de roche 707
crapet rouge 710
crapet-soleil 718
crapet vert 713
crappie, 744, 749
    black 744, **745–749**
    white **741–744**, 748
Crappies 699
crawpie 744, 749
crayon d'argent 654
creek chub, 406, **507–511**
    northern 511
creek shiner 452

- crested chub 433
- *Cristivomer* 221
  - *namaycush* 227
- Croakers, Drums *or* 811
- *crysoleucas, Abramis* 438
  - *Notemigonus* 332, 336, **434–438**
  - *Notemigonus crysoleucas* 435
- *crysoleucas auratus, Notemigonus* 435
- *crysoleucas bosci, Notemigonus* 435
- *Crysoleucas, Cyprinus* 438
- *Culaea* 664
  - *inconstans* **661–664**
- cutlips 414
- cutlips minnow **412–414**
- cutthroat, coastal 183
  - Yellowstone 183
- cutthroat trout **177–183**, 186
- *cuvieri, Gasterosteus* 668
  - *Gasterosteus bispinosus* 671
- *cyanellus, Apomotis* 710, 713
  - *Lepomis* **710–713**
- *cyanocephalus, Notropis umbratilis* 472
- *cyanonoton, Alosa* 120
  - *Pomolobus* 120
- *cyanopterus, Coregonus nigripinnis* 257
  - *Leucichthys* 259
- *cylindraceum, Prosopium* **286–291**
- *Cylindraceus, Salmo* 290
- (*Cylindrosteus*) *oculatus, Lepidosteus* 105
- (*Cynoperca*) *canadense, Stizostethium* 766
- *cyprinella, Ictiobus* 560
  - *Macrostomatobus* 560
  - *Megastomatobus* 560
  - *Sclerognathus* 560
- *cyprinellus, Ictiobus* **557–560**
- Cyprinidae 376
  - key to 378
- Cypriniformes 376
- Cyprinodontidae 630
  - key to 631
- Cyprinodontiformes 630, 651
- *Cyprinus* 376
  - (*Abramis*) *balteatus* 506
  - (*Abramis?*) *smithii* 331, 332, 336
  - *atratulus* 494
  - *atromaculatus* 511
  - *atronasus* 494
  - *auratus* 391
  - *bullaris* 514
  - *carpio* **407–411**
  - *Carpio* 411
  - (*Catastomus*) *aureolus* 583
  - (*Catastomus*) *Forsterianus* 535
  - (*Catastomus*) *Hudsonius* 463, 543
  - (*Catastomus*) *reticulatus* 535, 543
  - (*Catastomus*) *Sueurii* 583
  - *catostomus* 535
  - *Catostomus* 535
  - *Commersonnii* 543
  - *cornutus* 451
  - *corporalis* 514
  - *Crysoleucas* 438
  - (*Leuciscus*) *caurinus* 427
  - (*Leuciscus*) *chrysoleucas* 438
  - (*Leuciscus*) *gracilis* 487
  - (*Leuciscus*) *Oregonensis* 490
  - *maxillingua* 414
  - *megalops* 451
  - *smithii* 332
  - *sucetta* 553
  - *Tinca* 520
- *cyprinus, Carpiodes* **528–531**
  - *Carpiodes cyprinus* 530
  - *Catostomus* 530
  - *Labeo* 530
- *Cyprinus, Carpiodes* 530
  - *Catostomus* 530

- dace, 438, 452, 494, 515
  - Allegheny pearl 516
  - blacknose 459, **491–494**
  - Columbia River 490
  - eastern blacknose 491, 494
  - finescale **396–399**
  - Harvey Lake pearl 516
  - horned 511
  - leopard **498–500**
  - long-nosed 498
  - longnose **494–498**
  - nachtrieb 519
  - northern 519
  - northern pearl 516, 519
  - northern redbelly **392–395**
  - northwest 427
  - pearl **515–519**
  - red bellied 395
  - redbelly 395
  - redfin 494
  - redside **399–401**
  - Saskatchewan 487
  - shining 515
  - southern redbelly 393
  - speckled **501–502**
  - striped 494
  - western blacknose 491
- *dakotensis, Chrosomus* 395
- dallia 341
- *Dallia pectoralis* **338–341**
- Dalliidae 337
- dard à ventre jaune 786
- dard arc-en-ciel 782
- dard barré 789

dard de rivière 808
dard de sable 776
dard d'herbe 786
dard gris 802
dard noir 805
dard-perche 800
dard vert 779
darter, banded 782
  black-sided 805
  blackside 798, **803–805**
  blue 782
  central johnny 793, 797
  channel 798, **801–802**
  Copeland's 802
  eastern sand **775–776**
  fantail **787–789**
  green-sided 779
  greenside **777–779**
  Iowa **783–786**
  johnny **793–797**
  least **790–792**
  Manitou 800
  rainbow **780–782**
  river 798, **806–808**
  sand 776
  scaly johnny 793
  tessellated johnny 793
  weed 786
Darters 751
  key to 752
de sotoi, Acipenser oxyrhynchus 93
deep-water blob 847
deepwater chub 252
deepwater cisco 230, **250–252**
deepwater sculpin **842–847**
dekayi, Gasterosteus 674
Dekayii, Pygosteus 674
Delaware shad 132
deliciosus, Notropis 447, 469, 471, 474
  Notropis deliciosus 469
deliciosus stramineus, Notropis 469, 471, 476
delphinus, Minomus 550
dentex, Osmerus 311, 317
  Osmerus eperlanus 311, 317
  Osmerus mordax 312
dermatinus, Oncorhynchus 157
  Salmo 157
devilfish 341
diaphana, Hydrargira 634
diaphanus, Fundulus **631–634**
  Fundulus diaphanus 632, 636
  Zygonectus 634
diaphanus menona, Fundulus 632
dilatus, Spirinchus 318, 320
Diplesion blennioides 779
discobolus, Catostomus 550

dissimilis, Couesius plumbeus 403
  Erimystax 423, 424
  Luxilus 424
dog salmon 158
dogfish, 116, 345
  freshwater 116
Dolly Varden **214–219**
Dolly Varden char 219
Dolly Varden charr 219
Dolly Varden trout 215
dolomieu, Micropterus 733
  Micropterus dolomieu 733
dolomieui, Micropterus **728–734**
  Micropterus dolomieui 729, 733
dolomieui velox, Micropterus 729
doogler 614
doré 774
doré noir 767
Dorosoma cepedianum **133–137**
  cepedianum cepedianum 133
  cepedianum exile 134
  cepedianum heterurum 133
dorsalis, Notropis 385, 452
  Semotilus 511
dorsatus, Petromyzon marinus 70
drum, 531, 816
  freshwater **812–816**
Drums or croakers 811
duck-billed pike 374
duquesnei, Moxostoma **571–573**
Duquesnii, Catostomus 573
duquesnii, Moxostoma 573, 580, 585
  Placopharynx 570, 573
"dwarf" whitefish 270
dymondi, Coregonus reighardi 260

easgann 629
eastern banded killifish 632, 634
eastern blacknose dace 491, 494
Eastern brook trout 213
eastern carpsucker 531
eastern gizzard shad 137
eastern golden shiner 435, 438
eastern pickerel 374
eastern river chub 433
eastern sand darter **775–776**
eastern shiner 452
eastern silvery minnow 417
eastern speckled trout 213
eastern stickleback 668
eastern sucker 543
eastern whitefish 277
eel, 629
  American **624–629**
  Atlantic 629

  common 629
  European 624
  freshwater 629
  lamper 55, 65, 75
  lamprey 48, 55, 61, 68, 75
  silver 629
eelpout 645
Eels, 623
  Freshwater 623
egregius, Richardsonius 504
ekaluk 207
Elattonistius chrysopsis 331
elegans, Labeo 553
eleutherus, Noturus 620
  Schilbeodes 620
ellwife 128
elongata, Gila 401
elongatus, Clinostomus **399–401**, 508
  Leuciscus 401
  Luxilus 401
  Richardsonius 401
elver 629
emerald shiner, **440–443**
  common 443
  lake 440, 443
  river 440
emiliae, Notropis **453–545**
  Opsopoeodus 454
English brown trout 201
entomophagus, Coregonus 237
  Leucichtkys 266, 268
Entosphenus 36
  appendix 64
  japonicus 61
  japonicus septentrionalis 61
  lamottei 64
  lamottei japonicus 61
  lamottei lamottei 61, 64
  lamottenii 61, 64
  tridentatus **42–45**
  tridentatus ciliatus 42
  tridentatus tridentatus 42, 45
(*Entosphenus*) *japonica, Lampetra* 61
eos, Chrosomus **392–395**, 397
  Phoxinus 395
éperlan à petite bouche 310
éperlan arc-en-ciel 317
éperlan d'hiver 320
éperlan du nord 317
eperlanus dentex, Osmerus 311, 317
eperlanus mordax, Osmerus 311
eperlanus, Osmerus 311, 312, 317
  Osmerus eperlanus 311
  Salmo (*Osmerus*) 317
Eperlanus, Salmo 317
épinoche à cinq épines 664
épinoche à neuf épines 674
épinoche à quatre épines 660
épinoche à trois épines 668
épinoche tachetée 671
Episema jejuna 447
eqaluk 207
erebennus, Ictalurus natalis 596
eriensis, Argyrosomus 243
  Leucichthys 243
Erimystax dissimilis 423, 424
Erimyzon sucetta **551–553**
  sucetta kennerli 552
  sucetta kennerlii 553
  sucetta oblongus 553
  sucetta sucetta 552
Erinemus storerianus 422
eriox, Salmo 200
erythrogaster, Chrosomus 393, 395
erythrurum, Moxostoma **574–576**, 580, 585
erythrurus, Catostomus 576
escaille 96
escargot 96
escargot maillé 89
Esocidae 346
  key to 346
Esox 769
  amentus 365, 369
  americanus 353
  americanus americanus **348–351**, 353
  americanus umbrosus 355
  americanus vermiculatus **352–355**
  Boreus 363
  estor 357, 363, 365, 369
  immaculatus 369
  lucioides 357, 363, 365
  lucius 346, **356–363**
  Lucius 363
  lucius β americanus 351
  masquinongy **363–370**
  masquinongy immaculatus 365
  masquinongy masquinongy 365, 369
  masquinongy ohioensis 365
  niger **370–374**
  nobilior 357, 365, 369
  nobilis 357, 365, 369
  osseus 109
  reticulatus 374
  tridecemlineatus 374
  umbrosus 355
  vermiculatus 353, 355
estor, Esox 357, 363, 365, 369
esturgeon à museau court 82
esturgeon blanc 100
esturgeon de lac 89
esturgeon noir 96
esturgeon vert 92

Etheostoma aspro 805
  blennioides **777–779**
  blennioides blennioides 777
  blennioides pholidotum 778
  (Boleosoma) nigrum 753, 793
  boreale 786
  caerulea 782
  caeruleum **780–782**
  caeruleum caeruleum 781
  caeruleum notiale 781
  caeruleum oreium 781
  caprodes 800
  coerulea 782
  coeruleum 782
  exile **783–786**
  flabellare **787–789**
  flabellare flabellare 787
  flabellare lineolatum 787
  flabellaris 789
  güntheri 806, 808
  iowae 786
  microperca **790–792**
  nigra 797
  nigrum **793–797**
  nigrum eulepis 753, 794
  nigrum nigrum 753, 794
  nigrum olmstedi 753, 794
  olmstedi 753, 794
  olmstedi atromaculatum 794
  olmstedi olmstedi 794
  pellucidum 776
  quappella 786
Etheostomatinae 751
Eucalia inconstans 661, 664
  inconstans pygmaea 664
  pygmaea 664
eulachon **320–324**
eulakane 324
eulepis, Boleosoma nigrum 793
  Etheostoma nigrum 753, 794
Eupomotis auritus 710
  gibbosus 718
European brook lamprey 65
European brown trout 201
European carp 411
European char 207
European eel 624
European sea sturgeon 93
European smelt 312
European stickleback 668
exile, Dorosoma cepedianum 134
  Etheostoma **783–786**
exilis, Boleichthys 786
  Noturus 621
  Poecilichthys 786
Exocoetoidei 651
Exoglossum Lesurianum 414
  maxillingua **412–414**
Exomegas 36
extensus, Fundulus 634
eye-picker 414

falcata, Agosia 500
  Apocope 500
falcatus, Rhinichthys **498–500**
fallfish **511–515**
fantail, barred 787
  striped 787
fantail darter **787–789**
Fario clarkii 182
  gairdneri 191
  Lordii 219
  stellatus 182
fario, Salmo 198, 200
  Salmo trutta 198
fasciata, Cichla 733
Fasciatum, Pileoma 800
fasciatus, Centrarchus 733
  Fundulus 638
fathead minnow, **480–484**
  Harvey Lake 481
  northern 481, 484
  southern 481
fathom fish 324
federation pickerel 374
felis, Pimelodus 603
Felis, Silurus 603
ferox, Salmo 227
fiddler 197
fine-scale minnow 399
fine scaled sucker 543
finescale dace **396–399**
finescale mullet 573
finescale redhorse 573
finescale sucker 535
five-spined stickleback 664
flabellare, Etheostoma **787–789**
  Etheostoma flabellare 787
flabellare lineolatum, Etheostoma 787
flabellaris, Catonotus 789
  Etheostoma 789
  Poecilichthys 789
flathead catfish 609
flathead chub, **484–487**
  northern 485
  southern 485
Flavescens, Morone 761
flavescens, Perca **755–761**
  Perca fluviatilis 756, 761
flavus, Noturus **611–614**
fretensis, Hybopsis 468

- *flexuosus, Catostomus* 539
- *floridanus, Micropterus salmoides* 735
- *fluriatitis, Lampetra* 54
- *fluvialis, Petromyzon* 61
- *fluviatilis flavescens, Perca* 756, 761
- *fluviatilis intermedius, Perca* 756
- *fluviatilis, Lampetra* 56, 57
  - *perca* 761
  - *Perca* 756, 761, 774
  - *Perca fluviatilis* 756
- *Fluviatilis, Perca* 774
- Flyingfishes, Silversides *and* 651
- fondule barré 634
- *fontinalis, Baione* 213
  - *Salmo* 213
  - *Salvelinus* **208–213**
- *fontinalis hudsonicus, Salvelinus* 209
- *fontinalis timagamiensis, Salvelinus* 209
- *forbesi, Carpiodes* 529
- *formosa, Uranidea* 835
- *formosus, Cottus* 835
- *Forsterianus, Catastomus* 535
- *forsterianus, Catostomus* 535
- *Forsterianus, Catostomus* 539, 543
  - *Cyprinus (Catastomus)* 535
- *fossor, Ichthyomyzon* 46, **49–51**
- fourhorn sculpin, 843, 847
  - Great Lakes 847
- fourspine stickleback **658–660**
- *Franklini, Cottus* 835
- *franklini, Uranidea* 835
- fresh-water herring 336
- fresh-water killy 634
- freshwater cod 645
- freshwater dogfish 116
- freshwater drum **812–816**
- freshwater eel 629
- Freshwater eels 623
- freshwater herring 243, 256
- freshwater killifish 634
- freshwater mummichog 634
- freshwater sculpin 830
- freshwater smelt 317
- freshwater stickleback, common 664
- freshwater sturgeon 89
- *frontalis, Leuciscus* 451
- frost fish 291, 317
- *frost, Gadus* 649
- frostfish 649
- *fulvescens, Acipenser* **82–89**
- *fulvescens acutirostris, Acipenser* 83, 89
- *fulvescens obtusirostris, Acipenser* 83, 89
- *Fundulus diaphanus* **631–634**
  - *diaphanus diaphanus* 632, 636
  - *diaphanus menona* 632
  - *extensus* 634
  - *fasciatus* 638
  - *heteroclitus* 632, **635–639**
  - *heteroclitus heteroclitus* 636
  - *heteroclitus macrolepidotus* 632, 636
  - *nigrofasciatus* 638
  - *notatus* 631
  - *pisculentus* 638
- *furiosus, Noturus* 620
  - *Schilbeodes* 620
- *fusca, Hydrargyra* 345
- *fusiformis, Boleichthys* 786

- Gadidae 640
  - key to 641
- Gadiformes 640
- Gadinae 640
- *Gadus frost* 649
  - *lacustris* 645
  - *Lota* 645
  - *(Lota) maculosus* 645
  - *maculosus* 645
  - *pruinosus* 649
  - *tomcod* 649
- *gagei, Ichthyomyzon* 46
- *gairdneri, Fario* 191
  - *Salmo* **184–191**
- *Gairdnerii, Salmo* 191
- gar, 109
  - longnose **105–109**
  - northern longnose 109
  - short-nosed 105
  - shortnose 104, 105
  - spotted **103–105**
- garpike, 109
  - common 109
- Gars 101
  - key to 102
- gaspareau 128
- gaspereau 128
- Gasterosteidae 656
  - key to 657
- Gasterosteiformes 656
- *Gasterosteus aculeatus* **665–668**
  - *aculeatus leiurus* 665
  - *aculeatus trachurus* 665
  - *apeltes* 660
  - *atkinsi* 668
  - *atkinsii* 668
  - *Atkinsii* 668
  - *biaculeatus* 668, 671
  - *bispinosus* 668, 671
  - *bispinosus cuvieri* 671
  - *cataphractus* 668
  - *concinnus* 674
  - *cuvieri* 668

  dekayi 674
  gladiunculus 671
  globiceps 664
  gymnetes 664
  inconstans 664
  insculptus 668
  microcephalus 668
  millepunctatus 660
  nebulosus 674
  occidentalis 674
  pungitius 674
  pygmaeus 664
  quadracus 660
  serratus 668
  wheatlandi **669–671**
  Wheatlandi 671
gatte 689
gealag 201
Geotria 36
German 201
German brown trout 198, 201
German carp 411
German trout 201
gibbosa, Perca 718
gibbosus, Eupomotis 718
  Lepomis **713–718**
  Lepomus 718
Gila elongata 401
gila trout 185
gilae, Salmo 185
gilli 504
girardi, Cottus 830
gizzard fish 277
gizzard shad, **133–137**
  eastern 137
gladiunculus, Gasterosteus 671
Gladiunculus wheatlandi 671
glaucum, Stizostedion 768, 774
  Stizostedion vitreum 752, 768, 774
globiceps, Gasterosteus 664
Gloverii, Salmo 196
glut herring 120, 128
Gobio cataractae 498
  plumbeus 406
gobio, Cottus 839
goggle eye 707
golden carp 391
golden mullet 576
golden redhorse **574–576**
golden shad 128
golden shiner, 332, **434–438**
  eastern 435, 438
  southern 435
  western 435
golden trout 179, 185
goldeye, **327–332**
  western 332
  Winnipeg 332
goldfish **389–391**, 407, 438
gorbuscha, Oncorhynchus **148–152**
  Salmo 152
gourdhead buffalo 560
gracilis, Catostomus 539
  Cottus 835
  Cottus cognatus 827, 831
  Cyprinus (*Leuciscus*) 487
  Hybopsis 487
  Leuciscus 451
  Platygobio **484–487**
  Platygobio gracilis 485
  Uranidea 835
gracilis gulonella, Platygobio 485
grand brochet 363
grand corégone 277
grandis, Ptychocheilus 488
grass bass 749
grass pickerel, 351, **352–355**, 361, 374
  western 355
grass pike 355
grassfish 341
grassii, Leptocephalus 628
gravel chub **423–424**
gravelier 424
"gray bass" 816
gray herring 128
grayback 128, 634
grayback tullibee 243
grayling, 197, 294, 301, 305
  American 305
  arctic **300–305**
  Back's 305
  sailfin arctic 305
Grayling, salmons, trouts, chars, whitefishes *and*, key to 139
Graylings 300
"greaser" 262
Great grey trout 227
Great Lake catfish 605, 610
Great Lakes catfish 610
Great Lakes char 227
Great Lakes fourhorn sculpin 847
Great Lakes longear 727
Great Lakes mottled sculpin 827
Great Lakes muskellunge 369
Great Lakes sturgeon 89
Great Lakes trout 227
Great Lakes whitefish 277
great northern pickerel 363
great northern pike 363
great sea lamprey 75
greater redhorse **584–586**
green bass 734, 740

- green perch 713
- green pike 374
- green shad 128
- green-sided darter 779
- green sturgeon **90–92**
- green sunfish 709, **710–713**, 717, 723, 727
- *greeni, Couesius* 406
  - *Couesius plumbeus* 403
- Greenland charr 207
- greenside darter **777–779**
- grey pickerel 767
- grey pike 767
- grey pike perch 767
- grey sucker 543
- grey trout, 227
  - Great 227
- grilse 197
- grilt 197
- grindle 116
- Grindle, John A. 116
- grinnel 116
- *grisea, Lucioperca* 774
- *griseum, Stizostedion* 763
  - *Stizostedion canadense* 763, 766
- *Griseum, Stizostedium* 766
- *griseus, Catostomus* 535
- *Gristes nigricans* 733
- *grunniens, Aplodinotus* **812–816**
- grunter 816
- *Grystes megastoma* 740
  - *nigrisans* 733, 740
- gudgeon 438, 830
- *gulonella, Platygobio gracilis* 485
- *gulosus, Centridermichthys* 826
  - *Lepomis* 704
- *güntheri, Etheostoma* 806, 808
- *guttatus, Percopsis* 682
- *gymnetes, Gasterosteus* 664
- *gyrinus, Noturus* 612, **615–618**, 621
  - *Schilbeodes* 616, 618
  - *Silurus* 618
- *gyrinus sialis, Schilbeodes* 618

- *Hadropterus aspro* 805
  - *copelandi* 802
  - *maculatus* 805
  - *shumardi* 808
- *hankinsoni, Hybognathus* **414–416**
- *haplognathus, Lepomis megalotis* 725
- hardmouth 388
- *harengus, Leucichthys* 243
  - *Salmo (Coregonus)* 243
- Harvey Lake fathead minnow 481
- Harvey Lake pearl dace 516
- *harveyensis, Pimephales promelas* 481
- *Haustor* 605
  - *lacustris* 610
- Hearne's salmon 207
- *Hearnii, Salmo* 202, 207
- *Helioperca incisor* 723
  - *macrochira* 724
- herring, 256
  - Bear Lake 243
  - big-eye Mackenzie 265
  - big-eyed 128
  - blear-eyed 128
  - blueback **119–120**
  - branch 128
  - fresh-water 336
  - freshwater 243, 256
  - glut 120, 128
  - gray 128
  - lake **236–243**, 256, 265
  - sand 243
  - spring 128
  - summer 120
  - toothed 332, 336
  - wall-eyed 128
  - yellow 332
- Herring-like fishes 117
- herring of the lakes, toothed 336
- herring-salmon 243
- Herrings 117
  - key to 118
- *heteroclita, Cobitis* 638
- *heteroclitus, Fundulus* 632, **635–639**
  - *Fundulus heteroclitus* 636
- *heteroclitus macrolepidotus, Fundulus* 632, 636
- *heterodon, Alburnops* 456
  - *Hybopsis* 456
  - *Notropis* 439, **454–456**
- *heterolepis, Hybopsis* 459
  - *Notropis* **456–459**
  - *Notropis heterolepis* 457
- *heterolepis regalis, Notropis* 457
- *heterurum, Dorosoma cepedianum* 133
- hickory shad 137
- *Hiodon* 326
  - *alosoides* **327–332**, 336
  - *chrysopsis* 331, 336
  - *clodalis* 336
  - *Clodalis* 331
  - *selenops* 336
  - *tergisus* 332, **333–336**
- Hiodon, notch-finned 336
- Hiodontidae 326
  - key to 326
- *hirudo, Ammocoetes* 54
  - *Petromyzon* 54
- hog sucker, northern **554–557**
- hogmolly 557

hognose sucker 557
hognosed sucker 557
hogsucker, northern 557
Hoodii, Salvelinus 207
hooligan 324
horned dace 511
horned pout 604
hornedpout 594
hornpout 604
hornyhead 452
hornyhead chub **427–430**, 432
hoyi, Argyrosomus 250, 252
  Coregonus 230, 231, **246–250**
  Leucichthys 250
  Uranidea 835
Hoy's cisco 250
hubbsi, Catostomus columbianus 537
  Cottus 830
  Moxostoma **577–578**
Hudson Bay salmon 207
hudsonia, Clupea 463
hudsonicus, Salmo 209, 213
  Salvelinus fontinalis 209
hudsonius amarus, Notropis 460
hudsonius, Catostomus 535
  Hudsonius 463
  Notropis **459–463**
  Notropis hudsonius 460
Hudsonius, Catastomus 543
  Cyprinus (Catastomus) 463, 543
Hudsonius hudsonius 463
hudsonius saludanus, Notropis 460
hudsonius selene, Notropis 460
humpback 152
humpback salmon 152
humpback whitefish 277
Huro nigricans 740
  salmoides 740
(*Huro*) *nigricans, Perca* 740
Huronensis, Lepidosteus 109
  Lepisosteus 109
huronius, Argyrosomus 243
Huso 78
Hybognathus argyritis 417
  hankinsoni **414–416**
  nuchale 420
  nuchalis **417–420**
  nuchalis nuchalis 417
  nuchalis regius 417
  placitus 417
  regius 420
  stramineus 447, 471
  volucellus 476
Hybopsis 377, 403, 428, 431, 485
  anogenus 439
  bifrenatus 445
  biguttata 430
  blennius 447
  fretensis 468
  gracilis 487
  heterodon 456
  heterolepis 459
  kentuckiensis 430
  micropogon 433
  plumbea 406
  storeriana **420–422**
  storerianus 422
  volucella 476
  x-punctata **423–424**
  x-punctata trautmani 423
Hyborhynchus 377
  notatus 479
Hydrargira diaphana 634
  limi 345
  Multifasciata 634
Hydrargyra atricada 345
  atricauda 345
  fusca 345
hydrophlox 504
Hyodon alosoides 331
  tergisus 336
Hypentelium nigricans **554–557**
Hypomesus olidus **308–310**
  transpacificus 308
  transpacificus nipponensis 308
Hypsifario kennerlyi 171

I-mäñ'-ûk 341
Ichthyomyzon 36
  argenteus 48
  Argenteus 54
  bdellium 48, 54
  castaneus **46–48**, 54
  concolor 48, 54
  fossor 46, **49–51**
  gagei 46
  (*Reighardina*) *unicolor* 51
  unicuspis 46, 49, **52–55**, 70
Ictalarus nigricans 610
ictalops, Cottus 830
Ictaluridae 588
  key to 589
Ictalurus 605
  lacustris 610
  lacustris lacustris 605, 610
  lacustris punctatus 605
  melas **591–594**
  melas catulus 592
  melas melas 592, 594
  natalis **595–598**
  natalis erebennus 596
  natalis natalis 596

  nebulosus **598–604**
  nebulosus marmoratus 599
  nebulosus nebulosus 599, 603
  punctatus **604–610**
  punctatus punctatus 605, 610
Icthelis megalotis 727
Ictiobus bubalus 560
  Bubalus 560
  cyprinella 560
  cyprinellus **557–560**
immaculatus, Esox 369
  Esox masquinongy 365
  Salmo 213
Imostoma shumardi 808
incisor, Helioperca 723
inconnu **295–298**
inconstans, Culaea **661–664**
  Eucalia 661, 664
  Gasterosteus 664
inconstans pygmaea, Eucalia 664
inland whitefish 277
insculptus, Gasterosteus 668
intermedius, Perca fluviatilis 756
Iowa darter **783–786**
iowae, Etheostoma 786
  Oligocephalus 786
iridea, Salmo 191
irideus argentatus, Salmo 185, 191
irideus, Salmo 185, 191
ishikari-wakasagi 310
Isospondyli 117
ivitaruk 207

jack 363, 374
jackfish 363
jaculus, Alburnellus 443
japonica kessleri, Lampetra 59
japonica, Lampetra **58–61**, 62
  Lampetra (Entosphenus) 61
  Lampetra japonica 59
  Lampetra lamottei 58, 62
(japonica), Lethenteron 61
japonicus, Entosphenus 61
  Entosphenus lamottei 61
  Petromyzon 61
japonicus septentrionalis, Entosphenus 61
  Lampetra 59
jejuna, Episema 447
jejunus, Notropis 447
  Notropis blennius 446
  Paranotropis 447
johannae, Argyrosomus 252
  Coregonus 230, 231, **250–252**
  Leucichthys 236, 252
John A. Grindle 116
johnny darter, **793–797**
  central 793, 797
  scaly 793
  tessellated 793
jordani, Pantosteus 537, 548, 550
jordanii, Notropis 459
Jordan's sucker 550

Kamloops, Oncorhynchus 185, 191
  Salmo 191
kamloops, Salmo rivularis 191
Kamloops trout **184–191**
kamloops whitehousei, Salmo 185, 191
kelt 197
kendalli, Notropis 445
Kennebec salmon 197
kennerli, Erimyzon sucetta 552
kennerlii, Erimyzon sucetta 553
kennerlyi, Hypsifario 171
  Oncorhynchus nerka 166, 171
  Salmo 166
Kennerlyi, Salmo 171
Kennerly's salmon 171
kennicotti, Coregonus 277, 278, 280
  Coregonus nasus 280
kentuckiensis, Hybopsis 430
  Nocomis 430
kessleri, Lampetra japonica 59
keta 158
keta, Oncorhynchus **153–158**
keta vel kayko, Salmo 157
khlugu-zhey 280
kiack 128
kickininee 171
killifish, 634
  banded **631–634**
  common 639
  eastern banded 632, 634
  freshwater 634
  menona 634
  western banded 634
Killifishes 630
  key to 631
killy, fresh-water 634
king 177
king salmon 177
kirtlandi, Acipenser 89
kisutch, Oncorhynchus **158–164**
  Salmo 164
kiyi 230, **252–254**
kiyi, Coregonus 230, 231, **252–254**, 257
  Coregonus kiyi 253
  Leucichthys 254
kiyi orientalis, Coregonus 253
koelzi, Semotilus margarita 516

kokanee **165–171**, 209
kokani 171
krascheninnikovi, Salvelinus malma 215
kumlieni, Cottus bairdi 827
kyack 120
kyak 128

Labeo cyprinus 530
  elegans 553
Labidesthes sicculus **652–654**
labradoricus, Coregonus 277, 282
Labradoricus, Salmo (Coregonus) 277
Labrax albidus 692
  lineatus 697
  Lineatus 697
  notatus 692, 697
  osculatii 692
  pallidus 689
labrax, perca 697
Labrus auritus 710
  salmoides 740
lachrymale, Moxostoma 580
lacustris, 605
  Ameiurus 603, 605, 610
  Catostomus catostomus 532, 535
  Gadus 645
  Haustor 610
  Ictalurus 610
  Ictalurus lacustris 605, 610
  Lota lota 642, 645
  Villarius 610
lacustris punctatus, Ictalurus 605
laevis, Acipenser 89
lagocephalus, Oncorhynchus 157
Lahontan redside 504
lake Atlantic salmon 197
lake-bass, white 692
lake carp 531
lake catfish 610
lake chub **401–406**
lake chubsucker, **551–553**
  western 553
lake emerald shiner 440, 443
lake herring **236–243**, 256, 265
lake lamprey 75
lake northern chub 406
lake perch 761
lake pickerel 374
lake quillback 531
lake sculpin 847
lake shad 137
lake shiner 443
Lake St. John salmon 193
lake sturgeon **82–89**
Lake Superior longjaw 268
lake trout 183, 209, **220–227**
lake whitefish **269–277**
laker 227
lamarii, Acipenser 89
lamottei, Entosphenus 64
  Entosphenus lamottei 61, 64
  Lampetra 58, **62–65**
  Lampetra lamottei 58, 62
lamottei japonica, Lampetra 58, 62
lamottei japonicus, Entosphenus 61
lamottenii, Entosphenus 61, 64
  Lampetra 62
Lamottenii, Petromyzon 64
lamper 65
lamper eel 55, 65, 75
Lampetra 36, 42
  aurea 61
  ayresi **55–57**
  ayresii 57
  borealis 61
  cibaria 57
  (Entosphenus) japonica 61
  fluriatitis 54
  fluviatilis 56, 57
  japonica **58–61**, 62
  japonica japonica 59
  japonica kessleri 59
  japonicus septentrionalis 59
  lamottei 58, **62–65**
  lamottei japonica 58, 62
  lamottei lamottei 58, 62
  lamottenii 62
  planeri 66, 68
  richardsoni 55, **65–68**
  tridentata 45
  wilderi 64
lamprey, 75
  American brook 58, **62–65**
  Arctic **58–61**
  brook 51, 55, 65
  chestnut **46–48**
  European brook 65
  great sea 75
  lake 75
  landlocked sea 75
  Michigan brook 51
  nonparasitic brook 68
  northern 48, 55, 61
  northern brook **49–51**
  Pacific **42–45**
  Pacific river 61
  parasitic river 57
  river 48, **55–57**
  sea 45, **69–75**, 231
  silver 46, 48, 49, **52–55**, 70

  silvery 70
  small black 65
  small black brook 65
  southern brook 46
  three-toothed 45
  tridentate 45
  western 48, 57
  western brook 57, **65–68**
lamprey eel 48, 55, 61, 68, 75
Lampreys 36
  key to 37
lamproie à queue noire 57
lamproie arctique 61
lamproie argentée 55
lamproie brune 48
lamproie de l'est 65
lamproie de l'ouest 68
lamproie du nord 51
lamproie du Pacifique 45
lamproie marine 75
land-locked sockeye 171
landlocked salmon 197, 227
landlocked sea lamprey 75
la Queche 332
laquaiche argentée 336
laquaiche aux yeux d'or 332
large mouth bass 740
large mouthed bass 740
largemouth 740
largemouth bass, **734–740**
  northern 735, 740
largemouth black bass 740
largescale sucker 537, 542, **544–547**
lateralis, 504
  Abramis 506
  Leuciscus balteatus 506
  Mylocheilus 427
  Richardsonius 506
latior, *Coregonus* 277
lauretta 256
laurettae, *Argyrosomus* 256
  Coregonus 244, **255–256**
  Leucichthys 256
Lavinia alutacea 388
lawyer 116, 645
least cisco **262–265**
least darter **790–792**
leather carp 411
leefish 317
leiurus, *Gasterosteus aculeatus* 665
leopard dace **498–500**
Lepibema chrysops 692
Lepidomeda 376
Lepidosteus (*Cylindrosteus*) *oculatus* 105
  Huronensis 109
  osseus 109
  platostomus 105
Lepiopomus pallidus 723
lépisosté osseux 109
lépisosté tacheté 105
Lepisosteidae 101
  key to 102
Lepisosteiformes 101
Lepisosteus 101
  bison 109
  Huronensis 109
  longerostris 109
  oculatus **103–105**
  osseus **105–109**
  osseus oxyurus 109
  platostomus 103, 105
  productus 104, 105
  rostratus 109
  sinensis 101
Lepodosteus piquotianus 109
Lepomis auritus **707–710**
  Auritus 723
  cyanellus **710–713**
  gibbosus **713–718**
  gulosus 704
  macrochira 723
  macrochirus **719–724**
  macrochirus macrochirus 720, 724
  macrochirus purpurascens 720
  macrochirus speciosus 720
  megalotis **724–727**
  megalotis breviceps 725
  megalotis haplognathus 725
  megalotis megalotis 725
  megalotis peltastes 725, 727
  pallidus 723
Lepomus gibbosus 718
Leptocephalus grassii 628
leptura, *Lota lota* 642
Lestidium (*Bathysudis*) *parri* 324
lesueuri, *Moxostoma* 580, 583
Lesueurii, *Catastomus* 583
lesueurii, *Moxostoma* 580, 583, 585
Lesurianum, *Exoglossum* 414
Lethenteron appendix 64
  (*japonica*) 61
Leucichthys 230, 231
  alascanus 256
  alpenae 236
  artedi 243
  athabascae 266, 268
  autumnalis 246
  churchillensis 243
  cyanopterus 259
  entomophagus 266, 268
  eriensis 243
  harengus 243

    hoyi 250
    johannae 236, 252
    kiyi 254
    laurettae 256
    macrognathus 266, 268
    macropterus 243
    manitoulinus 243
    nigripinnis 259
    nipigon 243
    nueltinensis 243
    ontariensis 243
    prognathus 259
    pusillus 264
    reighardi 262
    sardinella 264
    sisco 243
    supernas 243
    tullibee 243
    zenithicus 268
leucichthys mackenzii, Stenodus 295, 298
leucichthys nelma, Stenodus 295, 298
leucichthys, Salmo 295, 298
    Stenodus **295–298**
    Stenodus leucichthys 295
Leuciscus argenteus 514
    atromaculatus 511
    atronasus 494
    balteatus 506
    balteatus lateralis 506
    canadensis 514
    carletoni 519
    cephalus 406, 511
    chrysoleucas 438
    copii 443
    cornutus 451
    elongatus 401
    frontalis 451
    gracilis 451
    margarita 519
    nachtriebi 518, 519
    neogaeus 399, 519
    nitidus 514
    oregonensis 490
    pulchellus 514
    rubrilateralis 519
    Storerianus 422
    vittatus 451
(Leuciscus) caurinus, Cyprinus 427
(Leuciscus) gracilis, Cyprinus 487
(Leuciscus) Oregonensis, Cyprinus 490
Leucosomus 516
    Americanus 438
    corporalis 514, 516
levenensis, Salmo 198, 200
    Salmo trutta 198
lewisi, Salmo 178, 183
    Salmo clarki 183
    Salmo clarkii 183
light-back tullibee 268
limi, Hydrargira 345
    Umbra **341–345**
lineatus, Labrax 697
    Roccus 697
Lineatus, Labrax 697
    Roccus 697
lineolatum, Etheostoma flabellare 787
ling, 645
    scaled 116
little pickerel 355
little redfish 171
little sucker 414
"little white basse" 689
loche 645, 649
Lochleven trout 198, 201
logperch, **797–800**
    northern 798
long ear sunfish 727
long-eared sunfish 727
long-finned smelt 320
long-finned sucker 531
long-nosed dace 498
longear, Great Lakes 727
    northern 727
longear sunfish 708, 710, 713, 717, 723, **724–727**
longears 710
longerostris, Lepisosteus 109
longfin smelt **318–320**
longirostris, Catostomus 535, 539
longjaw 236, 268
longjaw chub 236
longjaw cisco 230, **234–236**
longjaw, Lake Superior 268
longnose dace **494–498**
longnose gar, **105–109**
    northern 109
longnose sucker **531–535**, 542, 550
Lordii, Fario 219
lordii, Salmo 219
Lota, Gadus 645
lota lacustris, Lota 642, 645
lota leptura, Lota 642
Lota lota 640, **641–645**
    lota lacustris 642, 645
    lota leptura 642
    lota lota 642
    lota maculosa 642, 645
    maculosa 645
lota, Lota 640, **641–645**
    Lota lota 642
lota maculosa, Lota 642, 645
(Lota) maculosus, Gadus 645
Lotinae 640

- lotte 645
- *Lucio-perca Americana* 774
  - *Canadensis* 766
- *lucioides, Esox* 357, 363, 365
- *Lucioperca Americana* 774
  - *americana* 766
  - *Canadensis* 766, 774
  - *grisea* 774
- *lucius β americanus, Esox* 351
- *lucius, Esox* 346, **356–363**
  - *Lucius* 363
  - *Ptychocheilus* 488
- *Lucius, Esox* 363
- *Lucius lucius* 363
  - *masquinongy* 369
  - *reticulatus* 374
  - *vermiculatus* 355
- lunge 369
- lush 645
- *Luxilus cornutus* 452
  - *dissimilis* 424
  - *elongatus* 401
  - *selene* 463
- *Lythrurus umbratilis* 473

- Mackenzie herring, big-eye 265
- *Mackenzii, Salmo* 295, 298
- *mackenzii, Stenodus* 295, 298
  - *Stenodus leucichthys* 295, 298
- mackinaw trout 227
- *macrocephala, Muraena* 628
- *macrocheilus, Catostomus* **544–547**
- *macrochira, Helioperca* 724
  - *Lepomis* 723
- *macrochirus, Lepomis* **719–724**
  - *Lepomis macrochirus* 720, 724
- *macrochirus purpurascens, Lepomis* 720
- *macrochirus speciosus, Lepomis* 720
- *macrognathus, Coregonus* 237
  - *Leucichthys* 266, 268
- *macrolepidotum, Catostomus* 583
  - *Moxostoma* **579–583**, 585
- *macrolepidotus, Fundulus heteroclitus* 632, 636
- *macropterus, Leucichthys* 243
- *Macrostomatobus cyprinella* 560
- *maculata, Percina* **803–805**
- *maculatum, Boleosoma* 797
- *maculatus, Alvordius* 805
  - *Hadropterus* 805
- *maculosa, Lota* 645
  - *Lota lota* 642, 645
- *maculosus, Acipenser* 89
  - *Gadus* 645
  - *Gadus (Lota)* 645
- mad tom 618, 621
- madtom, brindled 618, **619–621**
  - northern 620
  - stonecat 614
  - tadpole **615–618**
- mailed fish, northern 109
- malachigan 816
- *Mallotus* 306
- (*Mallotus*) *pacificus, Salmo* 324
- *malma kraschéninnikovi, Salvelinus* 215
- *malma, Salmo* 215
  - *Salvelinus* 202, **214–219**
  - *Salvelinus alpinus* 215, 219
  - *Salvelinus malma* 215
- *Malma, Salmo* 219
- *malma spectabilis, Salvelinus* 215, 219
- *malma tudes, Salvelinus* 219
- malorotaya korioshka 310
- Manitou darter 800
- *manitoulinus, Leucichthys* 243
- marbled bullhead 604
- *Margariscus* 516, 519
  - *margarita* 519
- *margarita athabascae, Semotilus* 516
- *margarita, Clinostomus* 518
  - *Leuciscus* 519
  - *Margariscus* 519
  - *Semotilus* 397, **515–519**
  - *Semotilus margarita* 516
- *margarita koelzi, Semotilus* 516
- *margarita nachtriebi, Semotilus* 516
- maria 645
- marigane blanche 744
- marigane noire 749
- *marinus dorsatus, Petromyzon* 70
- *marinus, Petromyzon* **69–75**
- *marinus unicolor, Petromyzon* 70, 75
- *marmoratus, Ictalurus nebulosus* 599
  - *Rhinichthys* 498
- *marstoni, Salmo* 207
  - *Salvelinus* 202, 207
- masamacush 227
- maskinonge 369, 370
- maskinongé 369
- *masoni, Salmo* 191
- *masou, Oncorhynchus* 146
- *masquinongy, Esox* **363–370**
  - *Esox masquinongy* 365, 369
  - *Lucius* 369
- *masquinongy immaculatus, Esox* 365
- *masquinongy ohioensis, Esox* 365
- *maxillingua, Cyprinus* 414
  - *Exoglossum* **412–414**
- *Mayomyzon pieckoensis* 36
- *Meda* 376
- *medirostris, Acipenser* **90–92**
- *megalaspis, Acipenser* 89

Megalops Cepediana **137**
megalops, Cyprinus 451
  Notropis 451
megalotis breviceps, Lepomis 725
megalotis haplognathus, Lepomis 725
megalotis, Icthelis 727
  Lepomis **724–727**
  Lepomis megalotis 725
megalotis peltastes, Lepomis 725, 727
  Xenotis 727
Megapharynx valenciennesi 578
megastoma, Grystes 740
Megastomatobus cyprinella 560
melanops, Catostomus 562
  Minytrema **561–562**
melas, Ameiurus 594
  Ameiurus melas 594
  Ictalurus **591–594**
  Ictalurus melas 592, 594
melas catulus, Ictalurus 592
melas melas, Ameiurus 594
  Ictalurus 592
Melas, Silurus 594
meleagris, Rhinichthys atratulus 491
méné à grandes écailles 422
méné à nageoires rouges 452
méné à tête plate 487
méné bâton 433
méné bleu 468
méné camus 439
méné d'argent 420
méné de lac 406
méné de rivière 447
méné deux-barres 427
méné d'herbe 445
méné d'ombre 473
méné émeraude 443
méné laiton 416
méné long 401
méné paille 471
méné pâle 476
méné rose 507
Menominee whitefish 291
ménomini des montagnes 294
ménomini pygmée 285
ménomini rond 291
menona, Fundulus diaphanus 632
menona killifish 634
menton noir 456
meridionalis, 605
  Cottus 830
Merluccinae 640
Mesopus olidus 310
methy 645
meunier à grandes écailles 547
meunier à tête carrée 557
meunier de l'ouest 538
meunier des montagnes 550
meunier noir 543
meunier rouge 535
meunier tacheté 562
Michigan brook lamprey 51
microcephalus, Gasterosteus 668
Microcyprini 630
Microgadus proximus 646
  tomcod 640, **646–649**
microperca, Etheostoma **790–792**
  Microperca 792
Microperca microperca 792
  punctulata 792
  punctulatum 792
micropogon, Ceratichthys 433
  Hybopsis 433
  Nocomis **431–433**
Micropterus dolomieu 733
  dolomieu dolomieu 733
  dolomieui **728–734**
  dolomieui dolomieui 729, 733
  dolomieui velox 729
  punctulatus 733
  salmoides **734–740**
  salmoides floridanus 735
  salmoides salmoides 735
microstoma, Uranidea 820, 822
milesi, Pimephales 483
millepunctatus, Gasterosteus 660
Miller's thumb 830, 835
milneri, Nocomis 406
mimic shiner, **473–476**
  northern 474
minima, Cichla 733
minister 604
Minnilus cornutus 451, 452
  notatus 479
  selene 463
minnow, 634
  barred 634
  black-nosed 459
  blackhead 484
  bluntnose **476–479**
  brassy **414–416**
  bronze 399
  brook 494
  chub 406
  Columbia River 507
  cutlips **412–414**
  eastern silvery 417
  fathead **480–484**
  fine-scale 399
  Harvey Lake fathead 481
  Moose Lake 406
  mud 345

    Muskoka 459
    northern 519
    northern fathead 481, 484
    plumbeus 406
    poor 447
    pugnose **453–454**
    Richardson's 507
    salt water 639
    satin-finned 468
    shore 471
    silver-finned 468
    silver-sided 507
    silvery **417–420**
    silvery grey 500
    southern fathead 481
    spottail 463
    straw-coloured 447, 471
    western silvery 417
Minnows or carps 376
    key to 378
Minomus delphinus 550
Minytrema melanops **561–562**
mirror carp 411
Mississippi mud-minnow 345
missuriensis, Notropis stramineus 470
miurus, Noturus **619–621**
    Schilbeodes 621
mohawk chub 515
mollis, Schilbeodes 616, 618
montanus, 504
    Thymallus 301, 304
    Thymallus tricolor 304
mooneye, 254, **333–336**
    shad 332
    southern 336
mooneye cisco 259
Mooneyes 326
    key to 326
moonfish 749
Moose Lake minnow 406
Mordacia 36
mordax, Atherina 317
    Osmerus **310–317**
    Osmerus eperlanus 311
    Osmerus mordax 312
mordax dentex, Osmerus 312
Morone 683, 685, 689, 690, 692, 693, 697
    americana **684–689**
    Americana 689
    chrysops **689–692**
    Flavescens 761
    saxatilis **693–697**
Morrhua pruinosa 649
mottled sculpin, **826–830**
    Great Lakes 827
    northern 827
mountain sucker, 542, **547–550**
    northern 550
    plains 550
mountain trout 213, 227, 734
mountain whitefish **291–294**, 301
Moxostoma 563
    anisurum **564–567**, 578, 586
    Aureoleum 583
    aureolum 580, 583, 585, 586
    breviceps 580, 583
    carinatum **567–570**
    coregonus 580
    duquesnei **571–573**
    duquesnii 573, 580, 585
    erythrurum **574–576**, 580, 585
    hubbsi **577–578**
    lachrymale 580
    lesueuri 580, 583
    lesueurii 580, 583, 585
    macrolepidotum **579–583**, 585
    oblongum 553
    oblongus 553
    rubreques 580, 585, 586
    valenciennesi 567, 578, 580, **584–586**
moxostome cuivre 578
mud chub 511
mud minnow 345
mud-minnow, Mississippi 345
mud-perch 660
mud pickerel 351, 355, 374
mud pike 355
mud-pouch 660
mud shad 137
mud trout 213
mudcat 604
muddler, common slimy 835
    slimy 835
    spoonhead 842
mudfish, 116, 345
    western 116
mudminnow, central **341–345**
    western 345
Mudminnows 337
    key to 338
Mugiliformes 651
"mule whitefish" 270
"mules" 270
mulet à cornes 511
mulet perlé 519
mulet perlé du nord 519
mulhaden 120, 128
mullet, 531, 543
    black 543, 573
    broad 531
    common 583
    finescale 573

  golden 576
  river 570
  short-headed 583
  silver 567
  white nosed 567
Multifasciata, Hydrargira 634
mummichog, **635–639**
  common 639
  freshwater 634
mummy 639
Muraena anguilla 628
  argentea 628
  Bostoniensis 628
  macrocephala 628
  rostrata 628
  serpentina 628
muraena, Anguilla 628
museau noir 459
muskellunge, 357, 361, **363–370**
  Great Lakes 369
  Ohio 369
  tiger 361, 368, 369
  Wisconsin 369
Muskellunge, True Tiger 365
Muskoka minnow 459
muskoka, Notropis 459
musky, 369
  tiger 365
mykiss, Salmo 179, 183, 185
Mylocheilus caurinus **424–427**
  lateralis 427
Myoxocephalus quadricornis **842–847**
  quadricornis quadricornis 843
  quadricornis thompsonii 843, 846
  thompsoni 846
  thompsonii 846
Myxostoma anisura 567
  carpio 567, 578

nachtrieb dace 519
nachtriebi, Leuciscus 518, 519
  Semotilus margarita 516
namaycush 227
namaycush, Cristivomer 227
  Salmo 221, 227
  Salvelinus 219, **220–227**
Namaycush, Salmo 227
namaycush siscowet, Salvelinus 221
nannomyzon, Catostomus catostomus 532
Naresi, Salmo 207
  Salvelinus 207
narrow-mouthed bass 689
naseux de rapides 498
naseux léopard 500
naseux moucheté 502
naseux noir 494
nasus, Coregonus 270, **278–280**
  Salmo (*Coregonus*) 280
nasus kennicotti, Coregonus 280
nasutus, Argyreus 498
natalis, Ameiurus 598
  Amiurus 598
  Ictalurus **595–598**
  Ictalurus natalis 596
  Pimelodus 598
natalis erebennus, Ictalurus 596
native trout 213
nebulosus, Ameiurus 603
  Amiurus 603
  Gasterosteus 674
  Ictalurus **598–604**
  Ictalurus nebulosus 599, 603
  Pimelodus 603
nebulosus marmoratus, Ictalurus 599
needlenose 109
nelma, Salmo 295
  Stenodus leucichthys 295, 298
nelsoni, Coregonus 270
nelsonii, Coregonus 277
neogaea, Pfrille 399
neogaeus, Chrosomus 393, **396–399**
  Leuciscus 399, 519
  Pfrille 399
  Phoxinus 399
nerka kennerlyi, Oncorhynchus 166, 171
nerka, Oncorhynchus **165–171**, 209
  Oncorhynchus nerka 166
  Salmo 171
New York stickleback 668
niger, Esox **370–374**
nigra, Etheostoma 797
nigrescens, Silurus (*Pimelodus*) 603
  Thymallus 301
nigricans, Catostomus 556
  Gristes 733
  Huro 740
  Hypentelium **554–557**
  Ictalarus 610
  Perca (*Huro*) 740
  Petromyzon 54, 75
  Pimelodus 610
nigripinnis, Argyrosomus 259
  Coregonus 231, **256–259**
  Coregonus nigripinnis 257
  Leucichthys 259
nigripinnis cyanopterus, Coregonus 257
nigripinnis prognathus, Coregonus 257
nigripinnis regalis, Coregonus 257
nigrisans, Grystes 733, 740
nigro-maculatus, cantharus 749
  Pomoxis 749
nigrofasciatus, Fundulus 638

nigromaculatus, Pomoxis **745–749**
nigrum, Boleosoma 797
  Boleosoma nigrum 793
  Etheostoma **793–797**
  Etheostoma (*Boleosoma*) 753, 793
  Etheostoma nigrum 753, 794
nigrum eulepis, Boleosoma 793
  Etheostoma 753, 794
nigrum olmstedi, Boleosoma 793
  Etheostoma 753
nine-spined stickleback 674
ninespine stickleback **671–674**
nipigon, Coregonus 237
  Leucichthys 243
nipponensis, Hypomesus transpacificus 308
nitidus, Alburnus 443
  Leuciscus 514
  Salmo 202, 207
  Salvelinus 207
nobilior, Esox 357, 365, 369
nobilis, Esox 357, 365, 369
Nocomis 377
  biguttatus **427–430**
  kentuckiensis 430
  micropogon **431–433**
  milneri 406
nonparasitic brook lamprey 68
"normal" whitefish 270
North American Atlantic smelt 312
North Pacific Ocean smelt 312
North River shad 132
northeastern sand shiner 470
northern black bullhead 592
northern blacknose shiner 459
northern bluegill sunfish 724
northern brook lamprey **49–51**
northern brown bullhead 604
northern catfish 610
northern chub, 406
  lake 406
northern creek chub 511
northern dace 519
northern fathead minnow 481, 484
northern flathead chub 485
northern hog sucker **554–557**
northern hogsucker 557
northern lamprey 48, 55, 61
northern largemouth bass 735, 740
northern logperch 798
northern longear 727
northern longnose gar 109
northern madtom 620
northern mailed fish 109
northern mimic shiner 474
northern minnow 519
northern mottled sculpin 827
northern mountain sucker 550
northern pearl dace 516, 519
northern pickerel, great 363
northern pike, 351, 355, **356–363**, 368, 374
  great 363
northern redbelly dace **392–395**
northern redhorse 580, 583
northern rock bass 704, 707
northern sculpin 835
northern shorthead redhorse 583
northern smallmouth bass 734
northern squawfish **487–490**
northern sucker 535
northern yellow bullhead 598
northwest dace 427
notata, Perca 761
notatus, Fundulus 631
  Hyborhynchus 479
  Labrax 692, 697
  Minnilus 479
  Pimephales **476–479**
notch-finned Hiodon 336
Notemigonus chrysoleucas 438
  crysoleucas 332, 336, **434–438**
  crysoleucas auratus 435
  crysoleucas bosci 435
  crysoleucas crysoleucas 435
notiale, Etheostoma caeruleum 781
Notopteroidei 326
Notropis albeolus 459
  anogenus **438–439**, 454
  atherinoides 383, **440–443**
  atherinoides acutus 440
  atherinoides atherinoides 440
  bifrenatus **444–445**
  blennius **446–447**, 452, 469
  blennius jejunus 446
  cayuga 459
  chrysocephalus 383, 449
  cornutus 428, 432, **448–452**, 508, 513
  deliciosus 447, 469, 471, 474
  deliciosus deliciosus 469
  deliciosus stramineus 469, 471, 476
  dorsalis 385, **452**
  emiliae **453–454**
  heterodon 439, **454–456**
  heterolepis **456–459**
  heterolepis heterolepis 457
  heterolepis regalis 457
  hudsonius **459–463**
  hudsonius amarus 460
  hudsonius hudsonius 460
  hudsonius saludanus 460
  hudsonius selene 460
  jejunus 447
  jordanii 459

  kendalli 445
  megalops 451
  muskoka 459
  phenacobius 471
  photogenis 383
  reticulatus 447, 471
  rubellus 383, **463–466**
  rubrifrons 466
  scopiferus 463
  spilopterus **466–468**
  stramineus **469–471**, 474
  stramineus missuriensis 470
  stramineus stramineus 470
  umbratilis **472–473**
  umbratilis cyanocephalus 472
  volucellus 469, **473–476**
  volucellus buchanani 474
  volucellus volucellus 474
  whipplii 468
  whipplii spilopterus 468
Noturus 620
  eleutherus 620
  exilis 621
  flavus **611–614**
  furiosus 620
  gyrinus 612, **615–618**, 621
  miurus **619–621**
  platycephalus 614
  sialis 618
  stigmosus 620
novaeterrae, Anguilla 628
Novumbridae 337
nubilus, Rhinichthys 502
nuchale, Hybognathus 420
nuchalis, Hybognathus **417–420**
  Hybognathus nuchalis 417
nuchalis regius, Hybognathus 417
nueltinensis, Leucichthys 243

oblongum, Moxostoma 553
oblongus, Erimyzon sucetta 553
  Moxostomus 553
obtusirostris, Acipenser fulvescens 83, 89
occidentalis, Amia 116
  Gasterosteus 674
ocellicauda, Amia 116
ocellicaudata, Amia 116
oculatus, Lepidosteus (Cylindrosteus) 105
  Lepisosteus **103–105**
odonoghuei, Coregonus 277
Ohio muskellunge 369
ohioensis, Esox masquinongy 365
oilfish 324
olidus, Hypomesus **308–310**
  Mesopus 310
  Salmo (Osmerus) 310
Oligocephalus caeruleus 782
  iowae 786
olivaris, Pylodictis 609
olmstedi atromaculatum, Etheostoma 794
olmstedi, Boleosoma nigrum 793
  Etheostoma 794
  Etheostoma nigrum 753
  Etheostoma olmstedi 794
omble chevalier 207
omble de fontaine 213
ombre arctique 305
omisco 682
omisco-maycus, Percopsis 682
omisco maycus, Salmo 196
Omisco Maycus, Salmo 682
omiscomaycus, Percopsis **678–682**
Oncorhynchus 146
  biwa 146
  canis 157
  chouicha 177
  consuetus 157
  Cooperi 177
  dermatinus 157
  gorbuscha **148–152**
  Kamloops 185, 191
  keta **153–158**
  kisutch **158–164**
  lagocephalus 157
  masou 146
  nerka **165–171**, 209
  nerka kennerlyi 166, 171
  nerka nerka 166
  Scouleri 152
  tschawytscha 177
  tshawytscha **172–177**
ontariensis, Leucichthys 243
  Thymallus 301
  Thymalus 304
  Triglopsis 846
onychus, Cottus 842
oolichan 324
Opsopoeodus borealis 463
  emiliae 454
oquassa, Salmo 207
  Salvelinus 202, 207
orangespotted sunfish 713, 717, 723, 727
Oregon sturgeon 100
oregonense, Ptychocheilus 490
Oregonensis, Cyprinus (Leuciscus) 490
oregonensis, Leuciscus 490
  Ptychocheilus 425, **487–490**
oregonium, Prosopium 292, 294
oerium, Etheostoma caeruleum 781
orientalis, Coregonus kiyi 253
oscula, Agosia 502

  Apocope 502
  Corvina 816
  Sciaena 816
  Sciaena (Corvina) 816
osculatti, Labrax 692
osculus, Argyreus 502
  Rhinichthys **501–502**
Osmeridae 306
  key to 307
Osmerus 306
  albatrossis 324
  dentex 311, 317
  eperlanus 311, 312, 317
  eperlanus dentex 311, 317
  eperlanus eperlanus 311
  eperlanus mordax 311
  mordax **310–317**
  mordax dentex 312
  mordax mordax 312
  pacificus 324
  sergeanti 317
  spectrum 317
  thaleichthys 320
  viridescens 317
(Osmerus) eperlanus, Salmo 317
(Osmerus) olidus, Salmo 310
osseus, Esox 109
  Lepidosteus 109
  Lepisosteus **105–109**
osseus oxyurus, Lepisosteus 109
Ostariophysi 376
Oswego bass 749
ouananiche 197
ouananiche, Salmo 196
  Salmo salar 193, 196
ouitouche 515
oxyrhynchus, Acipenser **92–96**
  Acipenser oxyrhynchus 96
  Acipenser sturio 96
oxyrhynchus de sotoi, Acipenser 93
oxyurus, Lepisosteus osseus 109

Pacific brook char 219
Pacific brook trout 219
Pacific cod 157
Pacific lamprey **42–45**
Pacific river lamprey 61
Pacific salmons 146
Pacific smelt 320
Pacific sturgeon 100
pacificus, Osmerus 324
  Salmo (Mallotus) 324
  Thaleichthys **320–324**
Paddlefishes, Sturgeons *and* 77
pale-back tullibee 268
pallasi, Thymallus arcticus 304
Pallasii, Thymallus 304
pallidus, Catostomus 539
  Labrax 689
  Lepiopomus 723
  Lepomis 723
  Salmo 227
palouseanus, Catostomus columbianus 537
Pantosteus columbianus 537
  jordani 537, 548, 550
  platyrhynchus 548
Paranotropis jejunus 447
parasitic river lamprey 57
parkei, Salmo 219
  Salvelinus 215, 219
parkii, Salmo 219
parr 197
parri, Lestidium (Bathysudis) 324
parvus, Centridermichthys 826
  Cottopsis 825
paucidens, Salmo 171
peamouth **424–427**
peamouth chub 427
pearl dace, **515–519**
  Allegheny 516
  Harvey Lake 516
  northern 516, 519
pectoralis, Dallia **338–341**
pelican 96
pellucida, Ammocrypta **775–776**
  Ammocrypta (Ammocrypta) 776
  Salmoperca 682
pellucidum, Etheostoma 776
pellucidus, Pleurolepis 776
  Vigil 776
peltastes, Lepomis megalotis 725, 727
  Xenotis megalotis 727
Perca acuta 761
  americana 689, 761
  americanus 761
  chrysops 692
  flavescens **755–761**
  fluviatilis 756, 761, 774
  Fluviatilis 774
  fluviatilis flavescens 756, 761
  fluviatilis fluviatilis 756
  fluviatilis intermedius 756
  gibbosa 718
  (Huro) nigricans 740
  notata 761
  saxatilis 697
  vitrea 774
perca fluviatilis 761
  labrax 697
Percesoces 651

perch, 689, 756, 761
American 761
green 713
lake 761
log 800
pond 718
sea 689
silver 689
trout- **678–682**
white **684–689**
yellow **755–761**
"perch, white" 816
Perch-like fishes 683
perchaude 761
Perches 751
key to 752
Percichthyidae 683
key to 684
Percidae 751
key to 752
Perciformes 651, 683, 751, 817
Percina caprodes **797–800**
caprodes caprodes 798
caprodes carbonaria 798
caprodes semifasciata 798
copelandi **801–802**
maculata **803–805**
shumardi **806–808**
Percinae 751
Percomorphi 683
Percopsidae 677
Percopsiformes 677
Percopsis 678
guttatus 682
omisco-maycus 682
omiscomaycus **678–682**
transmontana 678
petit-bec 454
petit dard 792
petite morue 649
Petromyzon 36, 54
Americanus 75
appendix 64
argenteus 54
ayresii 56, 57
borealis 61
branchialis 68
concolor 54, 70, 75
fluvialis 61
hirudo 54
japonicus 61
Lamottenii 64
marinus **69–75**
marinus dorsatus 70
marinus unicolor 70, 75
nigricans 54, 75
plumbeus 56, 57
tridentatus 45
Petromyzontidae 36
key to 37
Petromyzontiformes 36
Pfrille 377, 397
neogaea 399
neogaeus 399
Phallostethiformes 651
phenacobius, Notropis 471
philonips, Cottus 835
pholidotum, Etheostoma blennioides 778
photogenis, Notropis 383
Photogenis rubrifrons 466
spilopterus 468
Phoxinus 377, 393, 397
eos 395
neogaeus 399
pickerel, 351, 355, 363, 374, 769, 774
banded 351
blue 767
bulldog 351
central redfin 355
chain 351, 361, **370–374**
eastern 374
federation 374
grass 351, **352–355**, 361, 374
great northern 363
grey 767
lake 374
little 355
mud 351, 355, 374
redfin **348–351**, 353, 361, 374
reticulated 374
sand 767
trout 351
wall-eyed 774
western grass 355
yellow 774
picquerelle 374
pidschian, Coregonus 270
pieckoensis, Mayomyzon 36
pike, 363, 374
black chain 374
blue 752, 767, 768
duck-billed 374
grass 355
great northern 363
green 374
grey 767
mud 355
northern 351, 355, **356–363**, 368, 374
red-finned 351
sand 767
wall-eyed 774
walleye 774

  yellow 774
pike-perch, 769, 774
  sand 767
  wall-eyed 774
pike perch, blue 767
  grey 767
  wall-eyed 774
  yellow 774
Pikes 346
  key to 346
Pileoma Fasciatum 800
  semifasciatum 800
  zebra 800
pilot fish 291
Pimelodus atrarius 603
  catus 603
  coenosus 598
  felis 603
  natalis 598
  nebulosus 603
  nigricans 610
  vulgaris 603
(*Pimelodus*) *borealis, Silurus* 610
(*Pimelodus*) *coenosus, Silurus* 598, 603
(*Pimelodus*) *nigrescens, Silurus* 603
Pimephales 377
  milesi 483
  notatus **476–479**
  promelas **480–484**
  promelas confertus 481
  promelas harveyensis 481
  promelas promelas 481
pin sucker 553
pinfish 660, 664, 668, 674
pink 152
pink salmon 146, **148–152**, 157
pinkster 82
piquotianus, Lepodosteus 109
pisculentus, Fundulus 638
placitus, Hybognathus 417
Placopharynx 578
  carinatus 570
  duquesnii 570, 573
Plagopterus 376
plains mountain sucker 550
planeri, Lampetra 66, 68
platostomus, Lepidosteus 105
  Lepisosteus 103, 105
platycephalus, Noturus 614
Platygobio 403
  gracilis **484–487**
  gracilis gracilis 485
  gracilis gulonella 485
platyrhynchus, Catostomus 537, **547–550**
  Pantosteus 548
Pleurolepis pellucidus 776
plumbea, Hybopsis 406
Plumbeus, Ceratichthys 406
plumbeus, Couesius 397, **401–406**, 519
  Couesius plumbeus 403
  Gobio 406
  Petromyzon 56, 57
plumbeus dissimilis, Couesius 403
plumbeus greeni, Couesius 403
plumbeus minnow 406
plumbeus rubrilateralis, Couesius 519
pocatello, Catostomus catostomus 532
Poecilichthys borealis 786
  caeruleus 782
  coeruleus 782
  exilis 786
  flabellaris 789
Poeciliidae 630
Pogonichthys communis 487
poisson bleu 305
poisson-castor 116
poisson de marais 116
poisson des chenaux 649
poisson doré 391
pollicaris, Cottus 842
  Uranidea 842
Polyodontidae 77
Polypteridae 101
Pomolobus aestivalis 120
  cyanonoton 120
  pseudo-harengus 128
  pseudoharengus 128
Pomotis appendix 710
  rubri-cauda 710
  vulgaris 718
Pomotus rubricauda 710
Pomoxis annularis **741–744**
  nigro-maculatus 749
  nigromaculatus **745–749**
  sparoides 749
Pomoxys sparoides 749
pond perch 718
pond smelt **308–310**
poor minnow 447
potbelly 494
Potomac shad 132
pottlebelly 494
poulamon atlantique 649
pout, horned 604
preblei, Prosopium 291
prickly bullhead 826
prickly sculpin **823–826**
productus, Lepisosteus 104, 105
prognathus, Argyrosomus 236, 250, 259
  Coregonus 257, 259
  Coregonus nigripinnis 257
  Leucichthys 259

promelas confertus, Pimephales 481
promelas harveyensis, Pimephales 481
promelas, Pimephales **480–484**
  Pimephales promelas 481
Prosopium 230, 285
  coulteri **282–285**
  coulterii 285
  cylindraceum **286–291**
  oregonium 292, 294
  preblei 291
  quadrilaterale 291
  snyderi 285
  williamsoni **291–294**
prosthemius, Ceratichthys 406
  Couesius 406
protrusus, Cottus 820, 822
proximus, Microgadus 646
pruinosa, Morrhua 649
pruinosus, Gadus 649
pseudo harengus, Clupea 128
pseudo-harengus, Pomolobus 128
pseudoharengus, Alosa **120–128**
  Pomolobus 128
Pseudoscaphyrhynchus 78
Ptychocheilus grandis 488
  lucius 488
  oregonense 490
  oregonensis 425, **487–490**
  umpquae 488
pugnose minnow **453–454**
pugnose shiner **438–439**
pulchellus, Leuciscus 514
pumpkinseed 709, **713–718**, 723
pumpkinseed sunfish 718
punctatissima, Anguilla 628
punctatus, 605
  Ictalurus **604–610**
  Ictalurus lacustris 605
  Ictalurus punctatus 605, 610
  Silurus 610
punctulata, Microperca 792
punctulatum, Microperca 792
punctulatus, Micropterus 733
pungitius, Gasterosteus 674
  Pungitius **671–674**
  Pygosteus 674
Pungitius pungitius **671–674**
punky 718
purpurascens, Lepomis macrochirus 720
purpuratus, Salmo 182, 185, 191
pusillus, Argyrosomus 264
  Coregonus 263, 264
  Leucichthys 264
pygmaea, Eucalia 664
  Eucalia inconstans 664
pygmaeus, Gasterosteus 664
pygmy whitefish **282–285**
Pygosteus Dekayii 674
  pungitius 674
Pylodictis olivaris 609

quadracus, Apeltes **658–660**
  Gasterosteus 660
quadricornis, Cottus 846
  Myoxocephalus **842–847**
  Myoxocephalus quadricornis 843
quadricornis thompsonii, Myoxocephalus 843, 846
quadrilaterale, Prosopium 291
quadrilateralis, Coregonus 290, 291
  Salmo (Coregonus) 291
quappella, Etheostoma 786
Quebec Red trout 202, 207
queue à tache noire 463
quiescens, Uranidea 835
quillback, **528–531**
  lake 531
quillback carpsucker 531
quillback sucker 531
quinnat 146, 177
quinnat, Salmo 177

racer 128
rainbow darter **780–782**
rainbow fish 782
rainbow smelt, **310–317**
  Arctic 312
  Atlantic 312
rainbow trout, 163, 179, **184–191**, 198
  coast 191
raseux-de-terre 797
red bellied dace 395
red-finned pike 351
red-horse, short-headed 583
Red River bass 816
red salmon 171
red-sided bream 507
red-sided shiner 401
red-sided sucker 535
red spotted char 219
red-spotted Rocky Mountain trout 219
red spotted trout 219
red sturgeon 89
red sucker 535, 583
red-throated trout 183
Red trout, Quebec 202, 207
redbelly dace, 395
  northern **392–395**
  southern 393
redbreast sunfish **707–710**, 713, 717, 723
redear sunfish 723
redeye 707

redeye bass 707
redfin dace 494
redfin pickerel, **348–351**, 353, 361, 374
    central 355
redfin shiner 452, **472–473**
redfish, little 171
redhorse, 386
    black **571–573**
    common 580, 583, 586
    copper **577–578**
    finescale 573
    golden **574–576**
    greater **584–586**
    northern 580, 583
    northern shorthead 583
    river **567–570**
    short-headed 585
    shorthead **579–583**
    silver **564–567**
    white nose 567
Redhorses 563
    key to 524
redmouth buffalo 560
redside dace **399–401**
redside, Lahontan 504
redside shiner **503–507**
regalis, Coregonus nigripinnis 257
    Notropis heterolepis 457
regius, Hybognathus 420
    Hybognathus nuchalis 417
Reighard cisco 262
reighardi, Coregonus 230, 231, **260–262**
    Coregonus reighardi 260
    Leucichthys 262
reighardi dymondi, Coregonus 260
Reighardina unicolor 51
(*Reighardina*) *unicolor, Ichthyomyzon* 51
Reighard's chub 262
residual sockeye 166
reticulated pickerel 374
reticulatus, Catostomus 539
    Cyprinus (*Catastomus*) 535, 543
    Esox 374
    Lucius 374
    Notropis 447, 471
Rheocrypta copelandi 802
Rhinichthys atratulus **491–494**
    atratulus atratulus 491
    atratulus meleagris 491
    atronasus 494
    cataractae **494–498**
    falcatus **498–500**
    marmoratus 498
    nubilus 502
    osculus **501–502**
rhothea, Cottus 838
    Uranidea 838
rhotheus, Cottus **837–838**, 839
rhynchaeus, Acipenser 89
ricei, Cottopsis 842
    Cottus 837, **839–842**
Rice's sculpin 842
richardii, Salmo 177
richardsoni, Catostomus 543
    Lampetra 55, **65–68**
Richardsoni, Cottus 830
    Uranidea 830
Richardsonii, Corvina 816
richardsonii, Trachidermus 825
Richardsonius balteatus **503–507**
    egregius 504
    elongatus 401
    lateralis 506
Richardson's minnow 507
riffle sucker 557
rivalis, Salmo 207
river chub, 428, **431–433**
    eastern 433
river darter **806–808**
river emerald shiner 440
river lamprey, 48, **55–57**
    Pacific 61
    parasitic 57
river mullet 570
river redhorse **567–570**
river shiner **446–447**
river whitefish 336
rivularis kamloops, Salmo 191
rivularis, Salmo 185, 191
roach, 438, 724
    American 438
robustus 605
Roccus 683
    americanus 689
    chrysops 692
    lineatus 697
    Lineatus 697
    saxatilis 697
rock bass, **703–707**
    northern 704, 707
rock sturgeon 83, 89
rockfish 697
Rocky Mountain trout, red-spotted 219
Rocky Mountain whitefish 294
rosarium, Acipenser 89
Rossii, Salmo 202, 207
rostrata, Anguilla **624–629**
    Muraena 628
rostratus, Catostomus catostomus 535
    Lepisosteus 109
rosy-faced shiner 466
rosyface shiner **463–466**

rough-head 452
roughnosed chub 515
round fish 291
round-nosed whitefish 280
round whitefish **286–291**
Round whitefishes 230
rubellus, Alburnus 443, 466
  Notropis 383, **463–466**
rubicundus, Acipenser 89
rubreques, Moxostoma 580, 585, 586
rubri-cauda, Pomotis 710
rubricauda, Pomotus 710
rubrifrons, Alburnus 466
  Notropis 466
  Photogenis 466
rubrilateralis, Couesius plumbeus 519
  Leuciscus 519
ruddy sturgeon 89
Rupertianus, Acipenser 89
rupestris, Ambloplites **703–707**
  Ambloplites rupestris 704, 707
  Bodianus 707
rupestris ariommus, Ambloplites 704
Rutilus Storerianus 422

Sacramento smelt 320
Sacramento squawfish 488
Sacramento sturgeon 100
sailfin arctic grayling 305
Sakhalin sturgeon 92
salar ouananiche, Salmo 193, 196
salar, Salmo **192–197**, 198
  Salmo salar 193
salar sebago, Salmo 193
Salmo 202
  aguabonita 185
  alipes 202, 207
  alpinus 207
  amethystus 227
  arcticus 304
  arcturus 207
  autumnalis 244
  bairdii 219
  brevicauda 183
  Campbelli 219
  canadensis 213
  canis 157
  clarki **177–183**
  clarki clarki 183
  clarki lewisi 183
  clarkii 183
  Clarkii 182
  clarkii alpestris 179, 183
  clarkii clarkii 183
  clarkii lewisi 183
  clupeaformis 269, 277
  confinis 227
  consuetus 157
  cooperi 177
  (Coregonus) Artedi 243
  (Coregonus) autumnalis 246
  (Coregonus) harengus 243
  (Coregonus) Labradoricus 277
  (Coregonus) nasus 280
  (Coregonus) quadrilateralis 291
  (Coregonus) tullibee 243
  Cylindraceus 290
  dermatinus 157
  Eperlanus 317
  eriox 200
  fario 198, 200
  ferox 227
  fontinalis 213
  gairdneri **184–191**
  Gairdnerii 191
  gilae 185
  Gloverii 196
  gorbuscha 152
  Hearnii 202, 207
  hudsonicus 209, 213
  immaculatus 213
  iridea 191
  irideus 185, 191
  irideus argentatus 185, 191
  Kamloops 191
  kamloops whitehousei 185, 191
  kennerlyi 166
  Kennerlyi 171
  keta vel kayko 157
  kisutch 164
  leucichthys 295, 298
  levenensis 198, 200
  lewisi 178, 183
  lordii 219
  Mackenzii 295, 298
  (Mallotus) pacificus 324
  malma 215
  Malma 219
  marstoni 207
  masoni 191
  mykiss 179, 183, 185
  namaycush 221, 227
  Namaycush 227
  Naresi 207
  nelma 295
  nerka 171
  nitidus 202, 207
  omisco maycus 196
  Omisco Maycus 682
  oquassa 207
  (Osmerus) eperlanus 317

  (*Osmerus*) *olidus* 310
  ouananiche 196
  pallidus 227
  parkei 219
  parkii 219
  paucidens 171
  purpuratus 182, 185, 191
  quinnat 177
  richardii 177
  rivalis 207
  rivularis 185, 191
  rivularis kamloops 191
  Rossii 202, 207
  salar **192–197**, 198
  salar ouananiche 193, 196
  salar salar 193
  salar sebago 193
  Scouleri 152
  sebago 192, 196
  spectabilis 219
  stagnalis 207
  stellatus 185, 191
  (*Thymallus*) *signifer* 304
  (*Thymallus*) *thymalloides* 304
  truncatus 191
  trutta **197–201**
  trutta fario 198
  trutta levenensis 198
  tschawytscha 177
  tsuppitch 164
  tudes 219
  warreni 177
salmoides, Aplites 740
  Huro 740
  Labrus 740
  Micropterus **734–740**
  Micropterus salmoides **735**
salmoides floridanus, Micropterus 735
salmon, 197
  arctic 207
  Atlantic **192–197**, 198, 202
  black 197
  blueback 171
  chinook 146, 163, **172–177**
  chum 146, 151, **153–158**
  coho 146, **158–164**
  common Atlantic 197
  Copper-mine River 207
  dog 158
  Hearne's 207
  Hudson Bay 207
  humpback 152
  Kennebec 197
  Kennerly's 171
  king 177
  lake Atlantic 197
  Lake St. John 193
  landlocked 197, 227
  pink 146, **148–152**, 157
  red 171
  sea-run 193
  sebago 197
  Sebago Lake 193
  silver 164
  sockeye 146, **165–171**
  spring 177
salmon-herring 246
salmon-trout 219
salmon trout 227
Salmonidae 138, 230
  key to 139
Salmoninae 138, 144
Salmons, 138
  Pacific 146
Salmons, trouts, and chars 144
Salmons, trouts, chars, whitefishes, grayling *and*,
    key to 139
Salmoperca pellucida 682
Salmopercae 677
salt water minnow 639
saludanus, Notropis hudsonius 460
salvation fish 324
Salvelinus 202
  alipes 207
  alpinus **201–207**
  alpinus malma 215, 219
  arcturus 207
  aureolus 202, 207
  bairdii 219
  fontinalis **208–213**
  fontinalis hudsonicus 209
  fontinalis timagamiensis 209
  Hoodii 207
  malma 202, **214–219**
  malma krascheninnikovi 215
  malma malma 215
  malma spectabilis 215, 219
  malma tudes 219
  marstoni 202, 207
  namaycush 219, **220–227**
  namaycush siscowet 221
  Naresi 207
  nitidus 207
  oquassa 202, 207
  parkei 215, 219
  spectabilis 219
  stagnalis 207
  timagamiensis 209, 213
sand darter, 776
  eastern **775–776**
sand herring 243
sand pickerel 767

sand pike 767
sand pike-perch 767
sand shiner, **469–471**
    northeastern 470
sapidissima, Alosa **128–132**
    Clupea 132
sapidissimus, Coregonus 277
sardinella, Coregonus **262–265**
    Leucichthys 264
Saskatchewan dace 487
satin-finned minnow 468
sauger **762–767**, 773
Sault whitefish 277, 282
saumon 197
saumon atlantique 197
saumon chinook 177
saumon coho 164
saumon d'eau douce 197
saumon keta 158
saumon nerka 171
saumon rose 152
sauvagesse du nord 490
saw-finned stickleback 668
sawbelly 128, 137
saxatilis, Morone **693–697**
    Perca 697
    Roccus 697
scaled ling 116
scaly johnny darter 793
Scaphyrhynchus 78
Schilbeodes 620
    eleutherus 620
    furiosus 620
    gyrinus 616, 618
    gyrinus sialis 618
    miurus 621
    mollis 616, 618
Sciaena caprodes 800
    (Corvina) oscula 816
    oscula 816
Sciaenidae 811
Sclerognathus cyprinella 560
scopiferus, Notropis 463
scorpion fish 847
Scouleri, Oncorhynchus 152
    Salmo 152
sculpin, 847
    Aleutian 822
    coastrange **820–822**
    Columbia 830
    deepwater **842–847**
    fourhorn 843, 847
    freshwater 830
    Great Lakes fourhorn 847
    Great Lakes mottled 827
    lake 847
    mottled **826–830**
    northern 835
    northern mottled 827
    prickly **823–826**
    Rice's 842
    shorthead **835–836**
    slimy **830–835**
    spoonhead **839–842**
    torrent **837–838**
Sculpins 817
    key to 818
Sea basses 683
sea char 219
sea lamprey, 45, **69–75**, 231
    great 75
    landlocked 75
sea perch 689
sea-run brook trout 208
sea-run salmon 193
sea sturgeon, 96
    European 93
sea trout 164, 183, 207, 208, 209, 213, 219
sebago 197
Sebago Lake salmon 193
sebago, Salmo 192, 196
    Salmo salar 193
sebago salmon 197
selene, Luxilus 463
    Minnilus 463
    Notropis hudsonius 460
selenops, Hiodon 336
semifasciata, Percina caprodes 798
semifasciatum, Pileoma 800
Semotilus atromaculatus **507–511**
    atromaculatus atromaculatus 508
    atromaculatus thoreauianus 508
    biguttatus 430
    bullaris 514
    corporalis **511–515**
    dorsalis 511
    margarita 397, **515–519**
    margarita athabascae 516
    margarita koelzi 516
    margarita margarita 516
    margarita nachtriebi 516
septentrionalis, Entosphenus japonicus 61
    Lampetra japonicus 59
sergeanti, Osmerus 317
serpentina, Muraena 628
Serranidae 683
serratus, Gasterosteus 668
seth 128
shad, 132, 137
    American **128–132**
    Atlantic 132
    common 132

  Connecticut River 132
  Delaware 132
  eastern gizzard 137
  gizzard **133–137**
  golden 128
  green 128
  hickory 137
  lake 137
  mud 137
  North River 132
  Potomac 132
  Susquehanna 132
  white 132
  young 438
Shad 332
shad mooneye 332
shallowwater cisco 243
sharpnose sturgeon 96
sheefish 298
sheep-nosed whitefish 280
sheepshead 816
shell back sturgeon 89
shiner, 463, 507, 749
  bigmouth **452**
  blackchin **454–456**
  blacknose **456–459**
  bridle **444–445**
  bridled 445
  common **448–452**
  common emerald 443
  creek 452
  eastern 452
  eastern golden 435, 438
  emerald **440–443**
  golden 332, **434–438**
  lake 443
  lake emerald 440, 443
  mimic **473–476**
  northeastern sand 470
  northern blacknose 459
  northern mimic 474
  pugnose **438–439**
  red-sided 401
  redfin 452, **472–473**
  redside **503–507**
  river **446–447**
  river emerald 440
  rosy-faced 466
  rosyface **463–466**
  sand **469–471**
  silver 383, 452, 507
  southern golden 435
  spotfin **466–468**
  spottail **459–463**
  western golden 435
shining dace 515
shore minnow 471
short-headed mullet 583
short-headed red-horse 583
short-headed redhorse 585
short-nosed gar 105
short-tailed trout 183
shorthead redhorse, **579–583**
  northern 583
shorthead sculpin **835–836**
shortjaw chub 268
shortjaw cisco 231, **265–268**
shortnose chub 262
shortnose cisco 230, **260–262**
shortnose gar 104, 105
shortnose sturgeon **80–82**
shortnosed sturgeon 82
shumardi, Cottogaster 808
  Hadropterus 808
  Imostoma 808
  Percina **806–808**
shuswap, Agosia 500
sialis, Noturus 618
  Schilbeodes gyrinus 618
sibiricus, Cottus 839
sicculum, Chirostoma 654
sicculus, Labidesthes **652–654**
Signifer, Coregonus 304
signifer, Salmo (*Thymallus*) 304
  Thymallus 301, 304
  Thymallus arcticus 304
signifer tricolor, Thymallus 304
Silurus borealis 605
  Felis 603
  gyrinus 618
  Melas 594
  (*Pimelodus*) *borealis* 610
  (*Pimelodus*) *coenosus* 598, 603
  (*Pimelodus*) *nigrescens* 603
  punctatus 610
silver bass 692, 744, 816
silver carp 531
silver chub **420–422**, 682
silver eel 629
silver-finned minnow 468
silver lamprey 46, 48, 49, **52–55**, 70
silver mullet 567
silver perch 689
silver redhorse **564–567**
silver salmon 164
silver shiner 383, 452, 507
silver-sided minnow 507
silver trout 171, 191
silverside, 452, 654
  brook **652–654**
Silversides 651

Silversides and flyingfishes 651
silversides, brook 654
silvery chub 511, 515
silvery grey minnow 500
silvery lamprey 70
silvery minnow, **417–420**
  eastern 417
  western 417
sinensis, Lepisosteus 101
sisco, Leucichthys 243
siscowet 221
siscowet, Salvelinus namaycush 221
siuslawi 504
six-spined stickleback 664
skipjack 128, 654
slimy muddler, 835
  common 835
slimy sculpin **830–835**
slink 197
small black brook lamprey 65
small black lamprey 65
small fish 324
small scaled sucker, Columbia 538
smallmouth bass, **728–734**
  northern 734
smallmouth black bass 734
smallmouth buffalo 560
smelt, 317
  American 317
  Arctic Ocean 312
  Arctic rainbow 312
  Atlantic rainbow 312
  European 312
  freshwater 317
  long-finned 320
  longfin **318–320**
  North American Atlantic 312
  North Pacific Ocean 312
  Pacific 320
  pond **308–310**
  rainbow **310–317**
  Sacramento 320
"smelt, boreal" 312
Smelts 306
  key to 307
smithii, Cyprinus 332
  Cyprinus (Abramis?) 331, 332, 336
smolt 197
smoothback 89
snake 374
snig 649
snyderi, Prosopium **285**
sockeye, 171
  land-locked 171
  residual 166
sockeye salmon 146, **165–171**
southern brook lamprey 46
southern fathead minnow 481
southern flathead chub 485
southern golden shiner 435
southern mooneye 336
southern redbelly dace 393
spantickle 668
sparoides, Pomoxis 749
  Pomoxys 749
spawneater 463
speciosus, Lepomis macrochirus 720
speckled bass 749
speckled cat 116
speckled char 213
speckled dace **501–502**
speckled trout, 213
  eastern 213
spectabilis, Salmo 219
  Salvelinus 219
  Salvelinus malma 215, 219
spectrum, Osmerus 317
spilopterus, Notropis **466–468**
  Notropis whipplii 468
  Photogenis 468
spinulosus, Cottus 839
Spirinchus dilatus 318, 320
  thaleichthys **318–320**
splake 209, 221
spoonhead muddler 842
spoonhead sculpin **839–842**
spotfin shiner **466–468**
spottail 463
spottail minnow 463
spottail shiner **459–463**
spotted bass 733
spotted catfish 605, 610
spotted chub 424
spotted gar **103–105**
spotted sucker **561–562**
spring 177
spring herring 128
spring salmon 177
square-tail 213
squaremouth 388
squaretailed trout 213
squawfish, Colorado 488
  Columbia 490
  northern **487–490**
  Sacramento 488
  Umpqua 488
stagnalis, Salmo 207
  Salvelinus 207
stargazer 835
steelhead 191

steelhead trout **184–191**
stellatus, Fario 182
  Salmo 185, 191
Stenodus 230
  leucichthys **295–298**
  leucichthys leucichthys 295
  leucichthys mackenzii 295, 298
  leucichthys nelma 295, 298
  mackenzii 295, 298
sterlyad 92
stevensi, Thaleichthys 324
stickleback, 660, 674
  blackspot 671
  blackspotted **669–671**
  bloody 660
  brook **661–664**
  common 664, 668
  common freshwater 664
  eastern 668
  European 668
  five-spined 664
  fourspine **658–660**
  New York 668
  nine-spined 674
  ninespine **671–674**
  saw-finned 668
  six-spined 664
  ten-spine 674
  threespine **665–668**
  twospine 668, 671
  twospined 671
  variable 664
Sticklebacks 656
  key to 657
Sticklebacks and relatives 656
stigmosus, Noturus 620
Stimpsonii, Triglopsis 846
Stizostedion canadense **762–767**
  Canadense 766
  canadense boreum 763
  canadense canadense 763, 766
  canadense griseum 763, 766
  glaucum 768, 774
  griseum 763
  vitreum **767–774**
  vitreum glaucum 752, 768, 774
  vitreum vitreum 752, 768, 774
Stizostedium canadense 766
  Griseum 766
Stizostethium Canadense 766
  (*Cynoperca*) *canadense* 766
stone-cat, brindled 621
stone catfish 614
stone sturgeon 89
stonecat, **611–614**
  tadpole 618
stonecat madtom 614
stoneroller 378, 557
storeriana, Hybopsis **420–422**
storerianus, Erinemus 422
  Hybopsis 422
Storerianus, Leuciscus 422
  Rutilus 422
Storer's chub 422
stramineus, Hybognathus 447, 471
  Notropis **469–471**, 474
  Notropis deliciosus 469, 471, 476
  Notropis stramineus 470
stramineus missuriensis, Notropis 470
straw-coloured minnow 447, 471
strawberry bass 749
striped bass **693–697**
striped dace 494
striped fantail 787
striped sucker 562
striper bass 697
sturgeon, Atlantic **92–96**
  black 83
  bony 89
  brown 83
  Columbia 100
  common 89, 96
  European sea 93
  freshwater 89
  Great Lakes 89
  green **90–92**
  lake **82–89**
  Oregon 100
  Pacific 100
  red 89
  rock 83, 89
  ruddy 89
  Sacramento 100
  Sakhalin 92
  sea 96
  sharpnose 96
  shell back 89
  shortnose **80–82**
  shortnosed 82
  stone 89
  white **96–100**
sturgeon sucker 535
Sturgeons 78
  key to 78
Sturgeons and paddlefishes 77
sturio, Acipenser 89, 93, 96
sturio oxyrhynchus, Acipenser 96
sucet de lac 553

sucetta, Cyprinus 553
    Erimyzon **551–553**
    Erimyzon sucetta 552
sucetta kennerli, Erimyzon 552
sucetta kennerlii, Erimyzon 553
sucetta oblongus, Erimyzon 553
suceur ballot 570
suceur blanc 567
suceur cuivre 578
suceur doré 576
suceur jaune 586
suceur noir 573
suceur rouge 583
sucker, 543
    bighead 557
    black 535, 543, 557, 562
    bluehead 542
    bridgelip **536–538**, 546
    chub 553
    coarse scaled 543
    coarsescale 547
    Columbia River 547
    Columbia small scaled 538
    common 543
    common white 543
    eastern 543
    fine scaled 543
    finescale 535
    grey 543
    hognose 557
    hognosed 557
    Jordan's 550
    largescale 537, 542, **544–547**
    little 414
    long-finned 531
    longnose **531–535**, 542, 550
    mountain 542, **547–550**
    northern 535
    northern hog **554–557**
    northern mountain 550
    pin 553
    plains mountain 550
    quillback 531
    red 535, 583
    red-sided 535
    riffle 557
    spotted **561–562**
    striped 562
    sturgeon 535
    Tahoe 550
    Utah 550
    white **538–543**, 546, 550
    white nosed 567
Suckers 523
    key to 524
sucking carp 463
suckleyi, Catostomus commersoni 539, 542
Sueuri, Catastomus 583
Sueurii, Cyprinus (Catastomus) 583
summer herring 120
sun bass 718
sunfish, 438, 718, 724, 816
    blue 724
    bluegill 717, 724
    common 718
    green 709, **710–713**, 717, 723, 727
    long ear 727
    long-eared 727
    longear 708, 710, 713, 717, 723, **724–727**
    northern bluegill 724
    orangespotted 713, 717, 723, 727
    pumpkinseed 718
    redbreast **707–710**, 713, 717, 723
    redear 723
    yellow 718
    yellowbelly 708, 710
Sunfishes 699, 751
    key to 700
sunny 718
supernas, Leucichthys 243
Susquehanna shad 132
syncheilus, Catostomus 537, 538
Synechoglanis beadlei 610
Synentognathi 651

tadpole cat 618
tadpole madtom **615–618**
tadpole stonecat 618
Tahoe sucker 550
tahoensis, Catostomus 550
tanche 520
taque 227
Temperate basses 683
    key to 684
ten-spine stickleback 674
tench **519–520**
tenuirostris, Anguilla 628
teres, Catostomus 539, 543
tergisus, Hiodon 332, **333–336**
    Hyodon 336
tessellated johnny darter 793
tête à taches rouges 430
tête-de-boule 484
tête rose 466
tezareh 280
tezra 280
thaleichthys, Osmerus 320
    Spirinchus **318–320**
Thaleichthys pacificus **320–324**

  stevensi **324**
thermophilus 504
the chub 252
thompsoni, Amia 116
  Carpiodes 529
  Myoxocephalus 846
  Triglopsis 846
Thompsoni, Carpiodes 530
thompsonii, Myoxocephalus 846
  Myoxocephalus quadricornis 843, 846
  Triglopsis 846
Thoracostei 656
thoreauianus, Semotilus atromaculatus 508
three-toothed lamprey 45
threespine stickleback **665–668**
Thymallidae 301
Thymallinae 138, 300
Thymalloides, Coregonus 304
thymalloides, Salmo (Thymallus) 304
Thymallus arcticus **300–305**
  arcticus pallasi 304
  arcticus signifer 304
  brevirostris 301
  montanus 301, 304
  nigrescens 301
  ontariensis 301
  Pallasii 304
  signifer 301, 304
  signifer tricolor 304
  thymallus 301
  tricolor 301, 304
  tricolor montanus 304
(Thymallus) signifer, Salmo 304
(Thymallus) thymalloides, Salmo 304
thymallus, Thymallus 301
Thymalus ontariensis 304
tiddler 668
tiger muskellunge 361, 368, 369
Tiger Muskellunge, True 365
tiger musky 365
tiger trout 198, 209
timagamiensis, Salvelinus 209, 213
  Salvelinus fontinalis 209
Tinca, Cyprinus 520
Tinca tinca **519–520**
  vulgaris 520
tinca, Tinca **519–520**
tiny burnstickle 674
Tirodon amnigenus 420
tittimeg 305
togue 227
tomcod, 649
  Atlantic **646–649**
tomcod, Gadus 649
  Microgadus 640, **646–649**
tommycod 511, 649
toothed herring 332, 336
toothed herring of the lakes 336
topminnow 634
torrent sculpin **837–838**
touladi 227
Trachidermus richardsonii 825
trachurus, Gasterosteus aculeatus 665
transmontana, Percopsis 678
transmontanus, Acipenser **96–100**
  Columbia 678
transpacificus, Hypomesus 308
transpacificus nipponensis, Hypomesus 308
trautmani, Hybopsis x-punctata 423
tricolor montanus, Thymallus 304
tricolor, Thymallus 301, 304
  Thymallus signifer 304
tridecemlineatus, Esox 374
tridentata, Lampetra 45
tridentate lamprey 45
tridentatus ciliatus, Entosphenus 42
tridentatus, Entosphenus **42–45**
  Entosphenus tridentatus 42, 45
  Petromyzon 45
Triglopsis ontariensis 846
  Stimpsonii 846
  thompsoni 846
  thompsonii 846
trout, 207, 219
  arctic 305
  aurora 209, 213
  blueback 207
  brook 170, **208–213**, 218, 221
  brown **197–201**, 209
  bull 219
  Clark's 183
  coast rainbow 191
  coastal cut-throat 183
  common brook 213
  Cranbrook 179
  cutthroat **177–183**, 186
  Dolly Varden 215
  Eastern brook 213
  eastern speckled 213
  English brown 201
  European brown 201
  German 201
  German brown 198, 201
  gila 185
  golden 179, 185
  Great grey 227
  Great Lakes 227
  grey 227
  Kamloops **184–191**
  lake 183, 209, **220–227**

  Lochleven 198, 201
  mackinaw 227
  mountain 213, 227, 734
  mud 213
  native 213
  Pacific brook 219
  Quebec Red 202, 207
  rainbow 163, 179, **184–191**, 198
  red spotted 219
  red-spotted Rocky Mountain 219
  red-throated 183
  salmon 227
  sea 164, 183, 207, 208, 209, 213, 219
  sea-run brook 208
  short-tailed 183
  silver 171, 191
  speckled 213
  squaretailed 213
  steelhead **184–191**
  tiger 198, 209
  von Behr 201
  western brook 219
  white 734
trout-perch **678–682**
Trout-perches 677
trout pickerel 351
Trouts, chars, salmon *and* 144
Trouts, chars, whitefishes, grayling, salmons *and*, key to 139
True Tiger Muskellunge 365
truite 201, 213
truite arc-en-ciel 191
truite brune 201
truite de mer 213
truite fardée 183
truite mouchetée 213
truncatus, Salmo 191
trutta fario, Salmo 198
trutta levenensis, Salmo 198
trutta, Salmo **197–201**
tschawytscha, Oncorhynchus 177
  Salmo 177
tshawytscha, Oncorhynchus **172–177**
tsuppitch, Salmo 164
tuberculatus, Catostomus 553
tudes, Salmo 219
  Salvelinus malma 219
tullibee, 238
  Argyrosomus 243
  Coregonus 244, 257
  Leucichthys 243
  Salmo (Coregonus) 243
tullibee, 243, 256
  black-back 259
  black-fin 259
  blueback 243
  grayback 243
  light-back 268
  pale-back 268
twospine stickleback 668, 671
twospined stickleback 671
tyee 177
tyrannus, Alosa 128

ulichan 324
Umbra limi **341–345**
umbratilis, Alburnus 473
  Lythrurus 473
  Notropis **472–473**
umbratilis cyanocephalus, Notropis 472
umbre de vase 345
Umbridae 337
  key to 338
umbrosus, Esox 355
  Esox americanus 355
Umpqua squawfish 488
umpquae, Ptychocheilus 488
unicolor, 51
  Ammocoetes 51
  Ichthyomyzon (Reighardina) 51
  Petromyzon marinus 70, 75
  Reighardina 51
unicuspis, Ichthyomyzon 46, 49, **52–55**, 70
Uranidea boleoides 835
  formosa 835
  franklini 835
  gracilis 835
  hoyi 835
  microstoma 820, 822
  pollicaris 842
  quiescens 835
  rhothea 838
  Richardsoni 830
Utah sucker 550
utawana, Catostomus commersonnii 539
uthlecan 324

valenciennesi, Megapharynx 578
  Moxostoma 567, 578, 580, **584–586**
variable stickleback 664
velifer, Carpiodes 529, 530
velox, Micropterus dolomieui 729
ventre citron 399
ventre-pourri 479
ventre rouge du nord 395
vermiculatus, Esox 353, 355
  Esox americanus **352–355**
  Lucius 355

- *vernalis, Alosa* 128
  - *Clupea* 128
- *Vigil pellucidus* 776
- *Villarius* 605
  - *lacustris* 610
- *viridescens, Osmerus* 317
- *vitrea, Perca* 774
- *vitreum glaucum, Stizostedion* 752, 768, 774
- *vitreum, Stizostedion* **767–774**
  - *Stizostedion vitreum* 752, 768, 774
- *vittatus, Leuciscus* 451
- *volucella, Hybopsis* 476
- *volucellus buchanani, Notropis* 474
- *volucellus, Hybognathus* 476
  - *Notropis* 469, **473–476**
  - *Notropis volucellus* 474
- von Behr trout 201
- *vulgaris, Ameiurus* 594, 603
  - *Amiurus* 603
  - *Anguilla* 628
  - *Pimelodus* 603
  - *Pomotis* 718
  - *Tinca* 520

- wall-eye 774
- wall-eyed herring 128
- wall-eyed pickerel 774
- wall-eyed pike 774
- wall-eyed pike perch 774
- wall-eyed pike-perch 774
- walleye, 752, 766, **767–774**
  - blue 768, 773
  - yellow 768, 773, 774
- walleye pike 774
- warmouth 704, 709, 717, 723
- *warreni, Salmo* 177
- waterbelly 254
- weed darter 786
- weepicheesis 332
- wendigo 221
- western banded killifish 634
- western blacknose dace 491
- western brook char 219
- western brook lamprey 57, **65–68**
- western brook trout 219
- western golden shiner 435
- western goldeye 332
- western grass pickerel 355
- western lake chubsucker 553
- western lamprey 48, 57
- western mudfish 116
- western mudminnow 345
- western silvery minnow 417
- *wheatlandi, Gasterosteus* **669–671**
  - *Gladiunculus* 671
- *Wheatlandi, Gasterosteus* 671
- *whipplii, Notropis* 468
- *whipplii spilopterus, Notropis* 468
- white bass **689–692**, 744
- white carp 531
- white cat 614
- white catfish 609
- white chub 515
- white crappie **741–744**, 748
- white lake-bass 692
- white nose redhorse 567
- white nosed mullet 567
- white nosed sucker 567
- white perch **684–689**
- "white perch" 816
- white shad 132
- white sturgeon **96–100**
- white sucker, **538–543**, 546, 550
  - common 543
- white trout 734
- whitefish, 277, 282
  - Atlantic **281–282**
  - broad **278–280**
  - brownback 285
  - common 277
  - Coulter's 285
  - "dwarf" 270
  - eastern 277
  - Great Lakes 277
  - humpback 277
  - inland 277
  - lake **269–277**
  - Menominee 291
  - mountain **291–294**, 301
  - "normal" 270
  - pygmy **282–285**
  - river 336
  - Rocky Mountain 294
  - round **286–291**
  - round-nosed 280
  - Sault 277, 282
  - sheep-nosed 280
  - Williamson's 294
- "whitefish, mule" 270
- Whitefishes, 230
  - grayling, salmons, trouts, chars *and*, key to 139
  - Round 230
- *whitehousei, Salmo kamloops* 185, 191
- whiting 515
- *wilderi, Lampetra* 64
- *williamsoni, Coregonus* 294
  - *Prosopium* **291–294**
- Williamson's whitefish 294
- windfish 438, 515

Winnipeg goldeye 332
winter cod 649
Wisconsin muskellunge 369

Xenotis megalotis peltastes 727
xestes, Acrocheilus 386
x-punctata, Hybopsis **423–424**
x-punctata trautmani, Hybopsis 423

yank 171
yellow belly bullhead 594
yellow bullhead, **595–598**
    northern 598
yellow catfish 598
yellow herring 332
yellow perch **755–761**
yellow pickerel 774
yellow pike 774
yellow pike perch 774
yellow sunfish 718
yellow walleye 768, 773, 774
yellowbelly 786
yellowbelly sunfish 708, 710
Yellowstone cutthroat 183
young shad 438
yshuh 324

zebra fish 800
zebra, Pileoma 800
zenithicus, Argyrosomus 268
    Coregonus 231, 237, **265–268**
    Leucichthys 268
Zygonectus diaphanus 634